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TO THE

EXECUTIVE DOCUMENTS

OF THE

HOUSE OF REPRESENTATIVES

FOR THE

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1876—'77.

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1877.

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TO

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OF THE

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REPORT

OF THE

SECRETARY OF WAR;

BEING PART OF

THE MESSAGE AND DOCUMENTS

COMMUNICATED TO THE

TWO HOUSES OF CONGRESS

AT THE

BEGINNING OF THE SECOND SESSION OF THE FORTY-FOURTH CONGRESS.

VOLUME III.

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1876.

REPORT

OF THE

CHIEF OF ORDNANCE.

REPORT OF THE CHIEF OF ORDNANCE.

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, October 10, 1876.

SIR: I have the honor to submit the following report of the principal operations of the Ordnance Department during the fiscal year ended June 30, 1876, with such remarks and recommendations as the interests of that branch of the military service seem to require.

The fiscal resources and disbursements of the Department during the year were as follows, viz:

Amount of appropriations in Treasury June 30, 1875	$262,534 88
Amount in Government depositories to credit of disbursing-officers on same date	255,709 26
Amount of deposits in Treasury not reported to the credit of the appropriations on the same date	11,686 24
Amount of appropriations from July 1, 1875, to June 30, 1876, including the fixed annual appropriation for arming and equipping the militia	1,348,837 99
Amount from appropriation from sales of ordnance material	75,000 00
Amount (net) received since June 30, 1875, on account of damages to arms in hands of troops, from sales of arms to officers, and of condemned stores, and from all other sources not before mentioned	441,575 84
Total	2,395,344 21

Amount of expenditures since June 30, 1875	$1,636,218 45
Amount deposited under appropriation for allowance under eight-hour law in excess of remittances	953 33
Amount deposited in Treasury during the fiscal year ending June 30, 1876, as miscellaneous receipts	402,884 07
Amount of deposits not reported to the credit of the appropriations on June 30, 1876	3,482 98
Amount in Government depositories to the credit of disbursing-officers on June 30, 1876	188,471 21
Amount turned into the surplus fund on June 30, 1876	14,893 24
Amount of appropriations in Treasury June 30, 1876	148,440 93
Total	2,395,344 21

The manufacture of rifles and carbines at the National Armory, and of metallic ammunition, infantry, cavalry, and horse equipments, and all minor ordnance stores and supplies, with their care and preservation, at our several arsenals; the distribution of all such supplies to the Army, militia, and Marine Corps, and designated colleges; the examination and testing of various inventions; the experiments with heavy cannon, field-guns, mitrailleuse, powder, projectiles, &c., at the proving-

ground at Sandy Hook; and the care and preservation of the different arsenals with their millions of public property, together with details at several of the headquarters of military divisions and departments, have given full employment to the officers of the corps.

Their stations and duties on October 1, 1876, were as follows: 2 at the Ordnance Office, 32 officers and 9 ordnance store-keepers at the arsenals, 4 at the Military Academy, 6 on the ordnance board and foundry duty, 7 at the headquarters military divisions and departments, 2 at the Centennial Exhibition, and 1 officer and 2 ordnance store-keepers on sick-leave.

APPROPRIATIONS.

The limited appropriations made by Congress, much below the estimates submitted by this bureau, have, in many instances, prevented the supplying of the Army on the frontier with that superior quality of ordnance stores which the nature of such service demands, and, in the attempt to utilize the material remaining on hand from the late war, every care and effort has been exercised in its selection and preparation to meet the wants of the troops, but with more or less dissatisfaction inseparable from the use of old material and obsolete patterns. Explanations to this effect have had to be made to officers in command of troops in defense of the action of this Department, where the responsibility for limited appropriations cannot rest. It is very natural that, in the rapid march of improvement in all war-supplies the world over, our soldiers, who are to perform most difficult and dangerous service, should insist upon the latest and most approved models and material of the best quality; and this Department has made every effort to respond to their every requirement with the funds at its disposal. The appropriations, therefore, for the use of this Department should be largely increased over those for the present fiscal year. The functions of the Ordnance Department are not limited to the mere supply of arms, &c., to our small Army, but are commensurate with the whole country. Its duties are national in their character and application. They are intended to prepare the *nation* for war. And, in deciding upon the moneys to be expended by it, the wants of the country at large in the event of war should be seriously considered, and not the comparatively trivial demands of an army of 25,000 men.

ARSENALS.

The appropriation of $40,000 for the "repairs of smaller arsenals, &c.," (fifteen in number,) is entirely inadequate. If the policy of Congress in regard to these arsenals is followed out many years longer, it will result in great loss to the Government in the deterioration of these valuable properties. The recommendation made by this bureau for several years, and the action of a board appointed under act of Congress,

strongly recommended by the Secretary of War, should be carried out. It is this: to concentrate the manufacturing operations of the Department at three arsenals and the armory, retain a few smaller arsenals for receipts and issues at central points, and sell all the others. I recommend the retention of Benicia Arsenal, on the Pacific; Rock Island Arsenal, in the Mississippi Valley; the National Armory, at Springfield, Mass.; the Frankford Arsenal, Pennsylvania; and the erection of an arsenal in the vicinity of New York out of the proceeds of the sales of those not required. The Allegheny, Watervliet, Watertown, and Washington Arsenals should be sold. The Indianapolis, Kennebec, Fort Monroe, Augusta, and San Antonio Arsenals should be retained as places of deposit, repair, and issue.

The concentration of our manufactures at a few points is essential to an economical administration of the affairs of the Department; but an equally strong reason lies in this, that certain products should not be separated in their manufacture, as instance the fact that arms are made at the Springfield Armory and ammunition for them at the Frankford Arsenal, when both these should be made at the same place, to insure that accuracy of detail, adjustment of parts, constant watchfulness of gauges, when a variation of one-thousandth part of an inch causes failure in the arm or cartridge, so necessary to secure perfect harmony in the operations that are to be used combined in one final result. And so with many other of our manufactures, where uniformity in quality and cost can only be attained by concentration at one point of production. This whole matter has been ably discussed by the board instituted last year under provision of law, and whose report accompanied my last annual report, and is deemed of sufficient importance to be again submitted.

SMALL-ARMS.

Only one hundred thousand dollars were appropriated for the manufacture of rifles and carbines at the National Armory during the present fiscal year, 1877. I have submitted an estimate of $500,000 for this object, and earnestly recommend that the appropriation of this amount be asked of Congress. During the ten years preceding the war—from 1852 to 1861—an average of $251,000 per annum was appropriated for the manufacture of arms, when the wants of a smaller army than the present and the cheapness of the arms then made permitted the gradual accumulation of them in store. On October 1, 1876, our returns show only 17,004 Springfield rifles and 3,684 Springfield carbines on hand, being a total of 20,688 arms of the approved service model. Our present appropriation, with what can be spared from the appropriation for arming and equipping the militia, will enable this Department to manufacture during the current year about 10,000. The demands from the Army, and requisitions from the militia on their respective quotas, will probably take 12,000 or 15,000, leaving in store at the end of the present fiscal year not more than 8,000 of these approved arms.

We have on hand many hundreds of thousands of muzzle-loading rifle-muskets of obsolete patterns, and a limited number of repaired breech-loaders, but modern wars must be fought with the most approved weapons, and none less perfect than the new-model Springfield will satisfy our soldiers. The principal European powers are at the present time replacing the arms used in the late wars on the continent by more improved models on the latest inventions; each nation striving to surpass her neighbors in the power and perfection of her arms. Such costly re-armaments show the great importance that is ascribed to securing the very best in their gigantic preparations for a possible conflict. Ought this country to be so blind to the possible wants of the future as to be willing to depend on obsolete weapons in store and the precarious supplies in the market? I deem it most vital to the interests of the nation that the manufacture of arms by this Department be steadily continued, in quantities sufficient to render a gradual accumulation of them in store a certainty. That a better arm than the Springfield may some day be invented is not at all improbable, and a magazine-gun will no doubt be the arm of the future, but until such an one suitable for the military service has been perfected and approved, a reserve stock of Springfields is a necessity. The affairs at the National Armory have been conducted in a most satisfactory manner under the skillful management of Lieut. Col. J. G. Benton, commanding.

MILITIA.

The necessity for an increase of the annual appropriation for arming and equipping the militia is so well understood and appreciated, has been so often referred to at length in official reports from this office and the War Department, that no lengthy discussion is called for.

The aggregate strength of the militia of the United States, as taken from the last Army Register, is as follows:

Organized	84,724
Unorganized	3,701,977

and only two hundred thousand dollars is annually appropriated for their arms and equipments. With our small standing army, the country must recruit its fighting-force from the people upon the breaking out of war. The soldiers who fought the battles of the rebellion, nearly half a generation ago, will soon pass from the scene, or become too old for active service, and most of the experience of the war will be lost to the country, with the actors in their graves. In a very few years dependence will have to be placed on the raw recruits; and while the experiences of the bivouac and battle cannot be acquired in peace and in the quiet avocations of ordinary life, much can be effected by placing in the hands of our young men the arms they may have to use in war, and encouraging that military spirit which alone can make material for soldiers. The distribution of arms to the militia is a vital element in this regard, and the want of a large standing army should be compensated by a well-organized, well-armed, and well-disciplined militia.

The act of March 3, 1875, provided for giving credit, under certain conditions, to the States and Territories for arms, &c., issued to them between 1861 and 1865, and charged under the law for arming and equipping the militia. The aggregate credit to be claimed, in case all the charges are removed under the conditions imposed by the law, amounts to $1,700,000. Credits have already been given to the extent of $420,000, and the latest model of breech-loading rifles and other stores have, in the majority of cases, been issued on account thereof. There is now due, and may become due, the various States and Territories on their respective quotas an amount sufficient to exhaust our limited stock of improved arms should a run be made upon it.

ARMS ISSUED TO STATES AND TERRITORIES.

The following joint resolution was passed at the last session:

"JOINT RESOLUTION authorizing the Secretary of War to issue arms.

"*Resolved by the Senate and House of Representatives of the United States of America in Congress assembled*, That the Secretary of War is hereby authorized to cause to be issued to the Territories and the States bordering thereon, such arms as he may deem necessary for their protection, not to exceed one thousand to said States each, and not more than five hundred to each of said Territories: *Provided*, That such issues shall be only from arms owned by the Government which have been superseded and no longer issued to the Army: *Provided, however*, That said arms shall be issued only in the following manner, and upon the following conditions, namely, upon the requisitions of the governors of said States or Territories showing the absolute necessity of arms for the protection of the citizens and their property against Indian raids into said States or Territories; also that militia companies are regularly organized and under control of the governors of said States or Territories to whom said arms are to be issued, and that said governor or governors shall give a good and sufficient bond for the return of said arms or payment for the same at such time as the Secretary of War may designate.

"Approved July 3, 1876."

Under the authority thus conferred, arms, &c., have been issued to the States of Kansas, Nebraska, and Texas, and to the Territory of Montana, the governors thereof having complied with the requirements of the joint resolution. The arms issued consist of 2,500 breech-loading rifled muskets, caliber .50; 1,000 breech-loading carbines, caliber .50; and 75,000 cartridges; the total money value being $69,560.

TARGET-PRACTICE.

The want of a thoroughly-digested system of target-practice for the use of the Army has long been felt. The effectiveness of the arm depends largely on the skill of the man who uses it, and some uniform

system should be devised for the education of the soldier in this respect. Portable and permanent targets of some approved pattern should be supplied to posts, and a regular drill for the practice should be fixed and authorized. This important matter has, in the past few years, received special attention, not only in the armies of the world, but among militia and private organizations. The attention of this Department has been directed to this subject for a long period, and many interesting experiments and valuable data have been accumulated, in order to render a preparation of a system of easy accomplishment. On the 15th May last I had the honor to address a letter to the Adjutant-General of the Army, recommending to the Hon. Secretary of War the appointment of a board of officers for the purpose of reaching a definite conclusion. I took occasion to state that "this very important subject has engaged the attention of this Department for some time, and is deemed vital to the efficiency of the soldier in the use of his weapon. A mass of information has been collected, the result of study and practical tests by ordnance officers, which will be submitted to the board."

WATER-POWER AT ROCK ISLAND ARSENAL.

On the 17th of February last I had the honor of submitting to the Hon. Secretary of War my report on the necessity for a special appropriation of $157,350 for completing the development of the water-power, inclosing a report thereon from the commanding officer of the Rock Island Arsenal. These reports were approved by the Secretary of War, and transmitted to the House of Representatives on the 19th of February, 1876. This item is included in the estimates from this office for the year 1878, and the necessity and propriety for an appropriation are fully set forth in the papers herewith submitted. This appropriation is required to carry out the agreements entered into by the Secretaries of War under the joint resolution of Congress of March 2, 1867, and there is no doubt that the interests of private parties require speedy action on the part of the United States. The work can be done more economically if the whole amount asked for be appropriated, and this is earnestly recommended.

ARTESIAN WELL AT BENICIA ARSENAL.

Lieutenant-Colonel McAllister, commanding, reports on the work performed during the past year in boring the artesian well at the Benicia Arsenal. By the 30th June, 1875, a depth of 1,049 feet had been reached. Since that date the depth of boring has been increased to 1,093 feet, but the insertion of the 7-inch pipe met with great difficulties and obstructions, which are graphically described, and which were successfully overcome with much ingenuity, perseverance, and patient labor. With the appropriation available it is hoped that the work will be accomplished, and an abundant supply of water obtained. In the present condition of the well, a deep-well pump put down 200 feet and kept

working eight hours delivered 15,000 gallons of water on the top of the hill. Even if we should ultimately fail in obtaining a flow of water above the surface of the ground, pumping will secure a permanent supply, although at considerable expense for labor and machinery.

INTERNATIONAL EXHIBITION—1876.

The great and continued interest manifested by the people of the whole country in the International Exhibition, and the acknowledged success of the exhibits made by the Executive Departments of the Government, induce me to give expression to the opinion that to Lieutenants Metcalfe and Whipple the entire credit should be given for the manner in which the exhibit of the Ordnance Department has been arranged and conducted. Beyond the selection of the articles to be sent to Philadelphia little was done by this Bureau, and all the details and arrangements for doing full justice to this most attractive feature of the exhibition were left to the judgment of these officers. Lieutenant Metcalfe has been constantly present and in immediate charge, and it is especially to his unwearied industry, his thorough knowledge of subjects and details, and his decided artistic tastes, that the interest and success of the ordnance exhibit are mainly due. The report of his operations, in charge of the ordnance section, War Department exhibit, is herewith submitted.

ARMAMENT OF FORTIFICATIONS.

Under this head I have submitted an estimate of $950,000 for the next fiscal year. The conversion of smooth-bore guns into efficient 8-inch rifles has progressed satisfactorily. The coiled wrought-iron tubes used in the conversion have been imported, but a trial of a gun with a tube of domestic manufacture has given the best results, and proved conclusively that our product is equal to the imported, notwithstanding the long experience in such work in English shops. Dependence can now be placed on the private enterprise and skill of our own people for the tubes for 8-inch rifles, and in the preparation of guns of that nature. Our material, labor, and machinery will meet all our requirements. The 8-inch rifle with American tube has successfully withstood over 500 rounds with battering charges, and remains in serviceable condition. Up to date, three guns of this class have been tested with the most satisfactory results—two 8-inch and one 9-inch caliber—all converted from 10-inch smooth-bores. Over 500 rounds were fired with battering charges from each 8-inch gun; and the 9-inch gun, with the same exterior model as the 8-inch, and consequently with thinner walls and less weight, was fired 502 rounds, which far more severely tested the system than the other two guns. It must now be conceded that the strength and value of conversions, by using coiled wrought-iron lining-tubes for 8-inch rifles, have been proved and established. The success which has attended these experiments at Sandy Hook, in the effort to utilize our

smooth-bore cast-iron guns by converting them into rifles of great power and efficiency, is a source of great satisfaction, and this uniform success justifies us in the conclusion that equally satisfactory results will follow our trials with the higher natures of 10-inch and 12-inch rifles, which are now in course of preparation. If our anticipations are realized in the success of these larger calibers, the Department will have developed a system of heavy ordnance at small expense which will compose an armament for our forts fully able to cope with foreign guns of equal caliber. Such a system will bring the manufacture entirely within the capacity of our private foundries, using our own raw material, and with no dependence on foreign establishments. It is but simple justice to give all the credit for the success that has been thus far achieved in this respect to Lieut. Col. S. Crispin, Constructor of Ordnance, and the other members of the Ordnance Board, Maj. T. J. Treadwell and Maj. T. G. Baylor, and the recorder, Capt. G. W. McKee; and I am confident that the final solution of these important questions, and others of a kindred character, could not be intrusted to safer or better hands. The detailed reports of the Constructor of Ordnance and of the Ordnance Board are herewith submitted, in the belief that the information conveyed will be found of great interest to the military profession and the country, and that the facts, figures, and results therein recorded will prove that most valuable progress has been made in the prosecution of these important investigations and experiments.

BREECH-LOADING CANNON.

Whatever differences of opinion may exist as to the relative merits and efficiency of muzzle and breech loading cannon of large caliber, (the former being exclusively used in England, the latter almost unversally adopted on the continent of Europe,) there can be no question that in casemated works the latter system possesses obvious and paramount advantages, such advantages as are generally admitted in determining on the proper armament for ships of war. The subject has, therefore, not escaped the attention of this Department, and the Board on Experimental Guns, of date the 10th June, 1875, "recognizing breech-loading rifles for casemate service to be a great desideratum, believed that a portion of the appropriation should be expended in this direction," and recommended "that a sufficient sum be used for the conversion of two 10-inch smooth-bore Rodman cast-iron guns into 8-inch breech-loading rifles," submitting at the same time specific plans of alteration, &c. The want of funds available for the purpose prevented any action thereon, but experiments to determine the feasibility of converting some of our smooth-bore Rodmans into breech-loading rifles should be undertaken at an early day.

EXPERIMENTAL GUNS.

Several experimental guns of large caliber, both muzzle and breech loading, that were manufactured under the act of June 6, 1872, have

been on exhibition at the Centennial Exhibition, by request of the respective inventors. It is the intention of the Department to have them removed to Sandy Hook, and ascertain their merits by actual trial, as soon as Congress appropriates the funds necessary for the purpose.

POWDER DEPOT AND MILLS.

An estimate of $100,000 has been submitted for the purchase of a site for a powder depot and mills, and commencing the erection of suitable buildings. The absolute necessity for this appropriation has been frequently stated and reported on heretofore, and special reference was made to it in my last annual report. The annual deterioration of gunpowder stored in our forts is about 12 per cent., and the prevention of this deterioration would in a few years more than repay the expense of establishing a suitable depot for its preservation. For experimental powders, the erection of a Government mill would be to the interest of the United States and of private manufactories, in enabling this Department to carry on experiments and fix standards for future guidance. It would be an economical measure, enabling the Department to make its own powder in time of peace at a less cost than now paid to private mills. Powder for heavy ordnance is made specially for the purpose, and requires special appliances and machinery for its manufacture. It is not marketable, and the quantity required being so limited as not to excite competition, high prices result. I submit the report of Lieut. Col. S. Crispin, Constructor of Ordnance, on the deterioration of powder, as an interesting paper bearing strongly on this subject.

INFRINGEMENT OF PATENTS.

In my last annual report I had the honor to renew at length previous recommendations on the subject of claims set up against this Department for alleged infringement of patents. During the last session of Congress the subject received the attention and consideration of both Committees on Patents, and resulted in a bill reported to the Senate, accompanied by a favorable report from the committee, recommending the passage of the bill at an early day. The papers in the case are herewith appended, and the hope is entertained that favorable action will be taken at the next session, that both the owners of patents and the Executive Departments may be relieved of much embarrassment in the prompt settlement of these vexed questions.

CLERICAL FORCE.

I beg leave to invite your attention to the necessity for an increase in the clerical force of this bureau. The number of clerks was reduced by late legislative enactment from eighteen to thirteen; one of class 4, one of class 3, one of class 2, and two of class 1. With the reduced force it will be impossible to keep up the work of the office, and very probably

the end of the present fiscal year will find us with at least one-third of the property-returns unexamined and other necessary work untouched. To give some idea of what has been done in this office during the past twelve months, the following statement is submitted:

Number of cash accounts of disbursing-officers examined and forwarded to the accounting-officers of the Treasury for settlement	288
Number of property-returns examined	3,706
Number of property-returns audited and closed	3,367
Number of requisitions received from the Army	1,287
Number of reports received from the armory, arsenals, and the Army on manufacture, trials, and tests of war-materials, &c	6,086
Number of letters received	11,172
Number of letters sent	15,925
Number of orders sent to the various arsenals for the issue of supplies	1,683

I have the honor to submit the following papers, heretofore referred to:

Appendix A.—Statement of principal articles procured by purchase and fabrication at the arsenals during the year ended June 30, 1876.

Appendix B.—Statement of ordnance, ordnance stores, &c., issued to the Regular Army and to posts during the year ended June 30, 1876.

Appendix C.—Apportionment of arms for the fiscal year ended June 30, 1876, under the law of 1808, for arming and equipping the militia, as amended by the seventh section of the act approved March 3, 1855, and regulations established in conformity therewith.

Appendix D.—Statement of ordnance, ordnance stores, &c., distributed to the militia from July 1, 1875, to June 30, 1876, under the law of 1808, as amended by the seventh section of the act approved March 3, 1855.

Appendix E.—Statement of ordnance, ordnance stores, &c., distributed to colleges from July 1, 1875, to June 30, 1876, under the joint resolution of May 4, 1870.

Appendix F.—Report of Lieut. Henry Metcalfe, Ordnance Corps, in charge of the ordnance exhibit of the War Department at the International Exhibition, 1876.

Appendix G.—Report of Lieut. Col. J. McAllister, commanding Benicia Arsenal, Cal., on progress of boring the artesian well.

Appendix H.—Report of Lieut. Col. Silas Crispin, Constructor of Ordnance, United States Army.

Appendix I.—Trial of the 9-inch converted rifle No. 3.

Appendix K.—Trial of the 8-inch converted rifle No. 2.

Appendix L.—Trial of the 8-inch converted rifle No. 5.

Appendix M.—Trial of the new-model five-barreled Gatling gun, cal. .45.

Appendix N.—Periodical reports on the construction of the experimental 10-inch Woodbridge muzzle-loading rifled gun, made by officers of the Ordnance Department stationed at Frankford Arsenal.

Appendix O.—Reports on the construction of the 9-inch Hitchcock muzzle-loading rifled gun, made by officers of the Ordnance Department stationed at the National Armory.

Appendix P.—Recommendations of a board of ordnance officers convened under the provisions of act of Congress approved March 3, 1875, in regard to the sale of arsenals.

Appendix Q.—Reports relative to infringement of patents.

Appendix R.—Development of the water-power at Rock Island Arsenal.

Appendix S.—Report of Lieut. Col. S. Crispin, Ordnance Department, on the deterioration of powder, caused by storage in sea-coast forts.

I have the honor to be, very respectfully, your obedient servant,

S. V. BENÉT,

Brigadier General, Chief of Ordnance.

The Hon. SECRETARY OF WAR.

APPENDIXES.

APPENDIXES.

APPENDIX A.

Statement of principal articles procured, by fabrication at the arsenals and by purchase, during the year ending June 30, 1876.

CLASS I.

48 Gatling guns, caliber .45.
1 Hotchkiss breech-loading field-gun, caliber 3.15.
1 9-inch Sutcliffe breech-loading rifle.
1 10-inch Woodbridge rifle.
1 12-inch Thompson breech-loading rifle.

CLASS II.

7 carriages for Gatling guns, caliber .45.
1 carriage for Hotchkiss breech-loading field-gun.
1 10-inch casemate-carriage, fitted with pneumatic buffers.
1 15-inch barbette-carriage, altered for 10-inch Woodbridge rifle.
1 15-inch barbette-carriage, altered for 12-inch Thompson rifle.
2 13-inch mortar-chassis.
121 parts of artillery-carriages.
1 hydraulic buffer for 20-inch gun-carriage.
1 set pneumatic buffers for 10-inch gun-carriage.

CLASS III.

5 breech-sights for 15-inch gun.
1 bucket, watering, iron.
42 chocks for barbette carriages.
1 dredging-box.
2 drag-ropes.
1 elevating-bar.
5 elevating arcs and indices.
2,326 feed-cases for caliber .45 Gatling guns.
1 gunners' gimlet.
1 pair gunners' sleeves.
10 gun-covers, various.
71 handspikes, various.
10 sets harness for Gatling gun, caliber .45.
6 sets harness for ambulances.
1 set harness for medical transport-cart.
16 harness-bags.
41 parts of artillery-harness.
2 ladles and staves.
6 lanterns.
3 mauls.
35 muzzle-sights.
5 oscillators for Gatling guns.
2 pass-boxes.
65 paulins, various.
5 pointing-cords.
1 pouch for pendulum-hausse.
166 priming-wires, assorted.

6 quoins.
27 rammers and staves, various.
8 scrapers, various.
75 securing-stakes.
4 sponge-covers, various.
15 sponges and rammers, various.
97 sponges and staves, various.
18 tompions, various.
238 vent-covers.
26 vent-pieces.
1 wiper for mortar.
2 worms and staves, field.
6 parts of artillery-implements.

Classes IV and V.

31 3-inch case-shot.
500 shell for 8-centimeter Prussian field-gun.
175 3-inch shell.
100 6-inch canister.
101 6-inch case-shot.
130 6-inch shell.
123 8-inch shot.
45 8-inch shell.
95 9-inch shot.
114 9.4-inch shot.
100 10-inch shot.
285 sabots, various.

Class VI.

1,017 Springfield "cadet" rifles, caliber .45.
20 Springfield "cadet" muskets, caliber .50.
1 Springfield carbine, caliber .45.
14,088 Springfield rifles, caliber .45.
24 shot-guns, double barrel.
670 Colt's revolvers, caliber .45, with appendages.
3,000 Schofield-Smith & Wesson revolvers, caliber .45, with appendages.
126 fencing muskets and bayonets.
100 cavalry officers' sabers.
16,665 spare parts for Springfield small-arms.
43 parts of cavalry officers' sabers.

Class VII.

3,588 sets infantry-equipments.
101 sets "Sherlock" infantry-equipments.
8 sets cavalry-accouterments.
7,115 graduated felt saddle-cloths.
8,168 sets knives, forks, and spoons.
74,902 parts of infantry-equipments.
56,043 parts of cavalry-accouterments.
82,164 parts of horse-equipments.
22,051 appendages for small-arms.

CLASS VIII.

41,972 cartridge-bags, filled, various.
40,911 cartridge-bags, empty, various.
7,301,306 metallic ball-cartridges, caliber .45.
201,175 metallic ball-cartridges, caliber .50.
671,881 metallic blank cartridges, caliber .45.
500 specimen cartridge cases and bullets, caliber .45.
150 pounds buckshot.
1,718 pounds powder.
1,065 electric cannon-primers.
2,000 fuses, paper, assorted.
100 fuses, McIntyre.
4,000 felt wads.
2,500 percussion-caps.
1,600 feet safety-fuse.
50 port-fires.
150 signal-rockets.
5,000 cartridge-primers.
800 cartridge-cases, metallic.

CLASS IX.

21 blocks, various.
124 chocks, various.
2 chronographs.
1 cradle for 20-inch gun.
1 densimeter.
3 elevating-apparatuses.
75 fencing-bayonets.
1 gun-lift for 15-inch gun.
1 gun-lift for 20-inch gun.
1 gun-truck.
1 ginfalls, garrison.
3 handcarts.
2 handspikes, gin.
7 hydraulic jacks.
1 loading-apparatus.
3 maneuvering-yokes.
3 platforms for mortars.
4 platforms for Wayne howitzer.
65 rollers, various.
26 shifting-planks.
1 sling-wagon for 10-inch gun.
2 trucks, cannon.
3 traverse-circles for pintles.

MISCELLANEOUS.

393 arm-chests.
33 aprons, smiths'.
8 ambulance-wagons.
5 ambulance-litters.
4 ambulance water-kegs.
5,594 boxes, packing.
2,356 buckles, assorted.
72 pounds black wax.

1 bullet-machine.
150 boxes cleaning materials, for cadets.
190 cans, tin.
1 cartridge heading-machine.
1 cartridge lining-machine.
1 electric conjunctor.
13 electric disjunctors.
1 firing-stand.
223 pounds fulminate of mercury.
35 gallons lacker.
2 medical transport-carts.
1 model of Woodbridge gun and plant.
1 model of Hitchcock forge.
1,148 pounds paint.
1 pressing-machine.
1 pressure dynamometer.
15 pressure-gauges, various.
1 recoil dynamometer.
32 soldiers' lockers.
50 sets saddler's tools.
1 target, velocimeter.
2 targets, small-arm.
1 tripod for Le'Boulengé chronograph.
15,922 tools and utensils, various.
1 velocimeter.
20 pounds wheel-grease.
920 copies rules and instructions for management of caliber .45 small-arms and Gatling guns.

APPENDIX B.

Statement of ordnance and ordnance-stores issued to the Regular Army and to posts during the year ending June 30, 1876.

CLASS I.

11 Gatling guns, caliber .45.
1 Gatling gun, caliber 1 inch.
1 6-pounder gun.
12 3-inch rifled guns.
2 light 12-pounder guns.
2 12-pounder mountain-howitzers.
2 24-pounder Coehorn mortars.
1 8-inch siege-mortar.

CLASS II.

11 Gatling gun-carriages.
6 6-pounder gun-carriages and limbers.
6 6-pounder gun-caissons and limbers.
4 10-pounder gun-carriages and limbers.
4 10-pounder caissons and limbers.
2 12-pounder prairie-howitzer carriages and limbers.
2 12-pounder mountain-howitzer carriages.
5 light 12-pounder gun-carriages and limbers.
5 12-pounder gun-caissons and limbers.
10 3-inch gun-carriages and limbers.
1 3-inch gun-caisson and limber.
2 12-pounder siege-gun carriages and limbers.
4 4½-inch gun-carriages and limbers.
2 18-pounder siege-gun carriages and limbers.
2 24-pounder mortar-beds, wood.
1 8-inch siege-howitzer carriage and limber.
1 8-inch mortar-bed.
1 traveling-forge, "A," with limber.
4 ambulance wagons.
1 medical transport-cart.
2 calvary-forges.

CLASS III.

1 set of harness for medical transport-cart.
4 sets of ambulance harness for 2 horses.
2 sets of Gatling gun harness for 2 near-horses.
2 sets of Gatling gun harness for 2 off-horses.
20 sets of artillery harness for 2 lead-horses.
15 sets of artillery harness for 2 wheel-horses.

CLASS IV.

24 12-pounder gun shot.
60 3-inch Absterdam shot.
120 4½-inch Hotchkiss shot.

26 12-pounder gun shell.
60 3-inch Eureka shell.
160 4½-inch Absterdam shell.
74 24-pounder gun shell.
200 24-pounder howitzer shell.
50 30-pounder Parrott shell.
60 100-pounder Parrott shell.
866 8-inch columbiad shell.
100 8-inch mortar shell.
2 15-inch gun shell.
100 3-inch Eureka case-shot.
20 12-pounder gun case-shot.

CLASS V.

85 12-pounder gun shot.
100 3-inch Hotchkiss shot.
48 12-pounder mountain-howitzer shell.
89 12-pounder gun shell.
100 3-inch Hotchkiss shell.
121 12-pounder gun case-shot.
48 12-pounder mountain-howitzer canister.

CLASS VI.

30 Sharps' carbines, caliber .50.
1,212 Springfield carbines, caliber .45.
120 Springfield muskets, caliber .50.
120 fencing muskets.
949 Colt's revolvers, caliber .45.
859 Schofield-Smith & Wesson revolvers, caliber .45.
140 Lee rifles, caliber .45.
939 Springfield rifles, caliber .45.
80 Springfield "cadet" rifles, caliber .45.
4 Springfield rifles, caliber .45, with trowel-bayonets.
25 breech-loading double barrel shot-guns.
16 light artillery sabers.
1,123 light cavalry sabers.
28 cadet swords.
173 musicians' swords.
20 non-commissioned officers' swords.

CLASS VII.

107 saber-belts, artillery.
97 saber-belt plates, artillery.
3 sets of cavalry accouterments.
1,750 carbine cartridge-boxes.
2,393 carbine cartridge-pouches.
2,918 carbine slings.
2,900 carbine-sling swivels.
3,695 pistol-belt holsters.
1,454 pistol cartridge-pouches.
70 saber-attachments.
2,925 saber-belts, cavalry.
2,939 saber-belt plates, cavalry.

1,118 saber-knots.
525 sets of infantry-equipments.
10 bayonet-scabbards, leather.
1,389 bayonet-scabbards, steel.
359 bayonet-scabbards, trowel.
1,007 brace-yokes.
11,328 canteens.
571 cap-pouches.
3,481 cartridge-boxes.
379 cartridge-boxes, No. 1.
161 cartridge-boxes, No. 2.
4,486 cartridge-loops.
30 cartridge-box belts.
230 cartridge-box plates.
30 cartridge-box belt-plates.
40 clothing-bags.
152 frogs, sliding.
7,999 great-coat straps.
2,327 gun-slings.
8,592 haversacks.
4,806 knapsacks.
250 sets knives, forks, and spoons.
2,153 meat-ration cans.
4 sword-belts, musicians' and non-commissioned officers'.
4 sword-belt plates, musicians' and non-commissioned officers'.
6,010 scabbards for intrenching-tools.
2,006 steady-straps.
206 tin cups.
998 valises.
91 waist-belts, musicians' and non-commissioned officers'.
91 waist-belt plates, musicians' and non-commissioned officers'.
400 waist-belt plates, cadet.
2,312 waist-belts, privates'.
2,288 waist-belt plates, privates'.
3,524 bridles, curb.
2,599 bridles, watering.
697 carbine-sockets.
8,074 curry-combs.
2,192 girths.
6,962 halters.
9,937 halter-straps.
10,622 horse-brushes.
6,826 lariats.
1,786 links.
6,028 nose-bags.
3,099 picket-pins.
2,370 saddles.
2 saddles, ambulance.
4,628 saddle-bags.
265 saddle-blankets, artillery.
8,148 saddle-blankets, cavalry.
4,356 saddle-cloths, felt.
4,846 side lines.
5,681 spurs.
6,009 spur-straps.
3,624 surcingles.

CLASS VIII.

Ammunition for small-arms.

150 pounds buck-shot.
768,760 carbine ball-cartridges, caliber .45.
221,100 carbine and rifle blank cartridges, caliber .45.
15,200 carbine and rifle blank cartridges, caliber .50.
14,300 center-primed metallic ball-cartridges, caliber .50.
10,500 canister for Gatling gun, caliber 1 inch.
13,000 elongated ball-cartridges for Gatling gun, caliber 1 inch.
4,000 felt wads.
2,500 percussion-caps, pistol.
10 pounds powder, duck.
100 pounds powder, musket.
374,690 revolver ball-cartridges, caliber .45.
66,600 revolver blank-cartridges, caliber .45.
750 revolver ball-cartridges, paper, caliber .44.
10,000 revolver blank-cartridges, Smith & Wesson, caliber .44.
622,200 rifle ball-cartridges, caliber .45.

Ammunition for field-guns.

2,423 blank cartridges, ½-pound charge.
732 blank cartridges, 1-pound charge.
8,559 blank cartridges, 3-inch gun.
6,550 blank cartridges, 6-pounder gun.
1,000 blank cartridges, 10-pounder gun.
15,283 blank cartridges, 12-pounder gun.
11,964 blank cartridges, 12-pounder mountain-howitzer.
200 electric cannon-primers.
125,529 friction primers.
18,525 pounds powder, cannon.
5,700 pounds powder, mammoth.
300 pounds powder, mealed.
16,900 pounds powder, mortar.
274 signal-rockets.

APPENDIX C.

Apportionment of arms for the fiscal year ending June 30, 1876, under the law of 1808 for arming and equipping the militia, as amended by the seventh section of the act approved March 3, 1855, and regulations established in conformity therewith.

States and Territories.	No. of Senators and Representatives.	Money-value.
Alabama	10	$4,797 85
Arkansas	6	2,878 71
California	6	2,878 71
Connecticut	6	2,878 71
Delaware	3	1,439 36
Florida	4	1,919 14
Georgia	11	5,277 64
Illinois	21	10,075 49
Indiana	15	7,196 78
Iowa	11	5,277 64
Kansas	5	2,398 93
Kentucky	12	5,757 42
Louisiana	8	3,838 28
Maine	7	3,358 50
Maryland	8	3,838 28
Massachusetts	13	6,237 21
Michigan	11	5,277 64
Minnesota	5	2,398 93
Mississippi	8	3,838 28
Missouri	15	7,196 78
Nebraska	3	1,439 36
Nevada	3	1,439 36
New Hampshire	5	2,398 93
New Jersey	9	4,318 06
New York	35	16,792 48
North Carolina	10	4,797 85
Ohio	22	10,555 27
Oregon	3	1,439 36
Pennsylvania	29	13,913 76
Rhode Island	4	1,919 14
South Carolina	7	3,358 50
Tennessee	12	5,757 42
Texas	8	3,838 28
Vermont	5	2,398 93
Virginia	11	5,277 64
West Virginia	5	2,398 93
Wisconsin	10	4,797 85
Arizona Territory*	3	1,439 36
Colorado Territory*	3	1,439 36
Dakota Territory*	3	1,439 36
Idaho Territory*	3	1,439 36
Montana Territory*	3	1,439 36
New Mexico Territory*	3	1,439 36
Utah Territory*	3	1,439 36
Washington Territory*	3	1,439 36
Wyoming Territory*	3	1,439 36
District of Columbia	3	1,439 36
Total	396	189,995 00
Freight, &c		11,005 00
		200,000 00

*Apportionment according to the first paragraph of the President's regulation of April 30, 1855.

APPENDIX D.

Statement of ordnance, ordnance stores, &c., distributed to the militia from July 1, 1875, *to June* 30, 1876, *under the law of* 1808, *as amended by the seventh section of the act approved March* 3, 1855.

CLASS I.

4 Gatling guns, caliber .45, with appendages.
2 10-pounder Parrott guns, 2.9-inch bore.
2 3-inch rifled guns, model 1861.
2 6-pounder bronze guns.
2 12-pounder bronze guns, light.

CLASS II.

4 carriages for caliber .45-inch Gatling guns.
6 carriages for 6-pounder, 10-pounder, and 3-inch guns.
2 carriages for light 12-pounder guns.

CLASS III.

18 sets artillery-harness for 2 wheel-horses.
8 sets artillery-harness for 2 lead-horses.
8 buckets, tar, iron.
5 buckets, sponge, iron.
2 fuse-cutters.
1 fuse-gouge.
2 fuse-plug wrenches.
2 fuse-wrenches.
7 gunners' gimlets.
15 gunners' haversacks.
2 gunners' pincers.
8 handspikes, trail.
16 harness-bags.
22 lanyards.
2 paulins, 5 by 5 feet.
4 paulins, 12 by 15 feet.
3 pendulum-hausses.
2 pendulum-hausse pouches.
2 pendulum-hausse seats.
7 pole-pads.
11 priming-wires.
3 prolonges.
4 rammer-heads.
6 sponges.
11 sponge-covers.
4 sponge-heads.
16 sponges and rammers.
16 thumbstalls.
2 tow-hooks.
9 tube-pouches.
6 vent-covers.
4 vent-punches.
7 worms and staves.

CLASSES IV AND V.

200 24-pounder mortar-shells.
101 light 12-pounder shot, fully prepared.
200 3-inch Hotchkiss shot, fully prepared.
24 light 12-pounder shell, fully prepared.
200 3-inch Hotchkiss shell, fully prepared.

CLASS VI.

1,800 Springfield muskets, caliber .50, model 1866.
4,283 Springfield muskets, caliber .50, model 1868.
20 Springfield muskets, caliber .50, model 1870.
21 Springfield "cadet" muskets, caliber .50, model 1869.
300 Springfield "cadet" rifles, caliber .45.
10,075 Springfield rifles, caliber .45.
345 Springfield carbines, caliber .45.
1,001 Spencer carbines, caliber .50.
2,000 French rifled muskets, caliber .69–.71.
1 Remington locking rifle, caliber .50.
1 Sharps' rifle, caliber .50.
1 Spencer rifle, caliber .50.
1 Ward-Burton breech-loading rifled musket, caliber .50.
1 Smith & Wesson revolver, caliber .44.
116 Schofield-Smith & Wesson revolvers, caliber .45.
212 Colt's revolvers, caliber .45.
54 officers' swords, with two scabbards and case, each.
225 light-artillery sabers.
360 light-cavalry sabers.
16 musicians' swords, with leather scabbards.
50 musicians' swords, with steel scabbards.
150 non-commissioned officers' swords, with leather scabbards.
12 non-commissioned officers' swords, with steel scabbards.
5 bayonets, extra.
100 firing-pins, extra.
100 firing-pin springs, extra.
5 rear-sights, complete.

CLASS VII.

200 sets infantry-equipments, pattern 1872.
1 set infantry-equipments, pattern 1874.
2,919 bayonet scabbards, leather.
8,386 bayonet-scabbards, steel.
3,521 cartridge-boxes, caliber .45, pattern 1874.
6,609 cartridge-boxes, caliber .58.
8,134 cartridge-box plates.
4,929 cartridge-box belts.
6,429 cartridge-box belt-plates.
11,681 gun-slings.
1,000 haversacks.
130 non-commissioned officers' shoulder-belts and plates.
40 non-commissioned officers' waist-belts and plates.
10,180 waist-belts.
11,755 waist-belt plates, privates.
60 tompions.

70 carbine cartridge-boxes.
100 pistol cartridge-boxes.
20 pistol cartridge-pouches.
126 pistol-belt holsters.
470 saber-belts and plates.
1,096 cavalry-saddles, with girths.
16 sets horse-equipments, complete.

CLASS VIII.

500 3-inch cartridge-bags, filled.
13 6-pounder cartridge-bags, filled.
817 light 12-pounder cartridge-bags, filled.
200 24-pounder cartridge-bags, filled.
5,000 revolver-ball cartridges, caliber .44.
20,000 revolver ball-cartridges, caliber .45.
13,600 carbine ball-cartridges, caliber .45.
76,200 rifle ball-cartridges, caliber .45.
240,000 musket ball-cartridges, caliber .50.
47,500 metallic blank cartridges, caliber .50.
9,820 friction-primers.
2,000 pounds mortar-powder.
5,000 percussion-caps.
15 yards slow-match.

APPENDIX E.

Statement of ordnance, ordnance-stores, &c., distributed to the colleges from July 1, 1875, *to June* 30, 1876, *under the joint resolution of May* 4, 1870.

2 8-inch mortars, with beds and platforms.
Implements and equipments for 2 8-inch mortars.
40 8-inch mortar-shells, strapped.
35 Springfield "cadet" muskets, caliber .50, model 1869.
25 musicians' swords, with steel scabbards.
20 non-commissioned officers' swords, with steel scabbards.
185 sets of cadet accouterments.
20 non-commissioned officers' waist-belts and plates.
20 sliding-frogs for waist-belts.
100 6-pounder cartridge-bags, filled.
100 light 12-pounder cartridge-bags, filled.
50 8-inch mortar-fuses.
150 friction-primers.
2,000 carbine-ball cartridges, caliber .50.
2,000 metallic blank cartridges, caliber .50.

APPENDIX F.

Report of Lieut. Henry Metcalfe, Ordnance Corps, in charge of the Ordnance Exhibit of the War Department at the International Exhibition, 1876.

INTERNATIONAL EXHIBITION, 1876,
Philadelphia, Pa., July 25, 1876.

SIR: In accordance with your directions, I have the honor to make the following report of my operations in charge of the Ordnance Section, War Department Exhibit, during the past year.

I have substantially carried out the plan originally proposed by me for the representation of the Ordnance Department. (See report of September 14, 1875.) This includes the mounting of the following heavy cannon, with their implements:

20-inch Rodman-gun; 13-inch sea-coast mortar, with center-pintle chassis; 9-inch Sutcliffe breach-loading rifle; $8\frac{4}{10}$ inch Mann breech-loading rifle; 8-inch converted muzzle-loading rifle, with model of casemate.

The 12-inch Thompson breech-loading rifle is exhibited, slung in the Laidley gun-lift, and the 10-inch Woodbridge muzzle-loading rifle, suspended in the Laidley hydraulic sling-wagon, both of these guns being so exhibited in order to utilize space, and at the same time to illustrate the functions of the two machines named.

This arrangement gives a fair idea of our heavy ordnance, characteristic specimens of all kinds now in use having been selected. The same idea is pursued in the representation of the carriages, the hydraulic buffer being represented with the 20-inch gun, the pneumatic buffer with the 8-inch rifle, and Sinclair's friction-brake being shown on the carriage for the Sutcliffe 9-inch rifle. The 20-inch gun is provided with a windlass of my devising for drawing it from battery with six men. These guns are all mounted on platforms of solid yellow pine, similar to that shown in the report on the 8-inch rifle. These platforms are supported on 4-foot piles, resting on transverse mud-sills, these precautions being necessary on account of the unstable nature of the ground, which is principally loose filling. Near each gun are shown specimens, fired and unfired, of the principal projectiles used in it, and within the building are sample cartridge-bags for each gun, filled with an excellent imitation of hexagonal powder, kindly made at my request by the Messrs. DuPont.

Within the building, arranged in proper groups, are shown specimens of all spherical projectiles, of the principal rifle-projectiles used during the war on both sides, many curious shot depending on air and gas rotation, and a separate collection of the principal rifle-projectiles of the present day. In proximity to them are shown the cartridges belonging to them.

Siege-guns are represented by the $4\frac{1}{2}$-inch muzzle-loading rifle and 8-inch howitzer with implements, both mounted, the former on Colonel Benton's iron carriage; and two 24-pound Coehorn mortars, mounted.

For field-guns, I have the light 12-pounder mounted on the wooden carriage, the 10-pounder Parrott on General Hagner's iron carriage, and the 3-inch rifle on Colonel Benton's iron carriage. To the limber of this is harnessed a model of a horse and artillery-driver, with a complete outfit of accouterments, equipments, and arms.

All breech-loading field-pieces are exhibited within the building mounted upon walnut skids, upon a massive table specially prepared for

them. On one side of it are shown the Sutcliffe, caliber 3″.15; the Moffat, 3″.07 caliber; the Mann, caliber 3″; and the Hotchkiss, caliber 3″.15. These are so placed as to be easily worked by hand. Opposite them are the Hotchkiss breech-loading mountain-rifle, caliber 1″.63; the experimental trial Woodbridge gun, caliber 2″.5, and four curious breech-loading rifled boat-howitzers, of presumably rebel origin. Along the middle line of the table, fronting each other, are a Whitworth rifle, and an old Spanish breech-loading piece about 1″.5 caliber, dated 1570, presented by Messrs. Morris, Wheeler & Co. It came from New Orleans, where it was probably dredged up from the bottom of the Mississippi. It bears every appearance of having been under water for many years, and is probably a relic of the Spanish occupation of Mexico. There are also of historic interest a siege-gun and Gribeauval carriage, (revolutionary), used at the battle of Saratoga; four guns known as part of an old Spanish battery, called after the twelve Apostles, a relic of the Spanish occupation of Louisiana, and probably ceded with that by the French; six 6-pounders and two 10-inch mortars, French, very ornate, supposed to have been presented to the Government by Lafayette. These, with the help of a festooning of bronzed chain, form an inclosure containing models of the Rodman, Hitchcock, and Woodbridge gun-plants, all on the scale of $\frac{1}{12}$, the Hitchcock model working as in actual practice, air being used instead of steam. All the tools, hooks, cranes, trucks, &c., of the latter process are faithfully represented. Near these models are shown specimens of the materials from which the guns are actually made; the wire for the Woodbridge gun being shown in coils, with the winding-apparatus, and an immense Danks sponge, in several stages of manufacture, standing near by. Specimens of the latter iron, twisted in every way, and rolled to the astounding tenuity of $\frac{1}{18525}$ inch, testify to its good quality when properly treated.

There are also tested specimens of various kinds of cannon material, with labels indicating the strains to which they have been subjected. There are also several bronze howitzers cast by Byers, in Philadelphia, 1777, one bearing the name "Mercer," presumably that of the then Master-General of the Ordnance, with his coat of arms. Another, probably cast later, bearing instead the more democratic device, "The people." Also, several 3-pounder howitzers, cast by D. King, Germantown, probably at about the same time, and associated with the name of "Mad" Anthony Wayne.

The following machine or mitrailleuse guns are shown. They form a historical series, beginning constructively with the Vandenburgh volley-gun; then the Requa battery; the Guthrie and Lee repeating two-barrel gun, and the Union repeating or coffee-mill gun. Then is shown the Gatling gun, short barrel, caliber .45, mounted on the new cavalry-carriage, to which is harnessed the stuffed horse, "George M. Patchen," and a horse-shaped trestle, with the driver's saddle, detachable single-tree, &c., complete. A cavalry forge-cart, similarly attached, is also represented. There is also the Hotchkiss revolving cannon, 1″.63 caliber, and the smaller mitrailleuse on the same plan. Two mountain-howitzers, one packed and the other on the prairie-carriage, complete this show of cannon, with exception of a large collection of models of field, siege, and sea-coast cannon and carriages.

Under the head of cannon-ammunition, beside the display already spoken of, I expose gunpowder in very many forms, especially including General Rodman's early inventions of perforated cake-powder, both hexagonal and in large short cylinders pasted together to form the cartridge. Specimens of gunpowder of various sizes and of different

nationalities are also shown; also a collection of 74 fuses, primers—friction and electric—and various means formerly employed in firing cannon.

The small-arm collection is epecially full; it contains 53 specimens of muzzle-loading military guns, 154 of breech-loaders, all of them different in principle or in purpose, 47 pistols and revolvers, and a miscellaneous collection of swords, sabers, and knives. Almost all prominent military systems, domestic or foreign, are here shown. The small-arms are arranged according to the classification adopted by me in preparing Ordnance Memoranda XV. This classification has stood the test of the introduction of so many new systems remarkably well.

In small-arm ammunition I have profited largely by Capt. William Prince's excellent collection of bullets, powder-cartridges, and cartridge-cases, without which this exhibit would have been very incomplete. In connection with this are shown all principal varieties of cartridge-cases in progressive stages of manufacture, targets made with the service-rifle at different ranges, &c.

In leather-work are shown a historical series of accouterments mounted on lay-figures, from the supposititious minute-man armed with a flint-lock musket used at the battle of Bunker Hill to the infantry soldier of the present day with the new equipment and the addition of the cartridge-block and trowel-bayonet. Besides these two figures there are represented the rifleman of 1815–1820 with the Hall breech-loading rifle; the infantry soldier of the Mexican war with the percussion-musket, model 1842; the cavalry soldier of the war of the rebellion with the Spencer repeating carbine and cartridge-box; the infantry soldier of the same epoch armed with the Springfield muzzle-loading rifle-musket; the infantry soldier of the present day with the full set of new equipments armed with the Springfield rifle, caliber .45, and a cavalryman, mounted, with the entire outfit prescribed in Ordnance Memoranda No. 18, and armed with Springfield carbine, and Colt's revolver, caliber .45, and saber.

The most interesting feature of the section of which I have charge is the machinery. This consists of a full set of cartridge-machines, 19 in number, making 5,000 blank cartridges, caliber .45, per day, and 21 machines of a typical character at work upon component parts of the Springfield rifle, caliber .45. The former are run by operatives detailed from the Frankford Arsenal as a branch of that establishment, and the latter by armorers similarly detached from the National Armory. The former go to and from their work as usual; the latter live in tents in Camp Knox within the Exhibition grounds, and are fed at the United States mess-house near by. The product of all this work is turned in as a regular part of the daily fabrication of the two establishments referred to. This machinery is run by power obtained from two 10-horse-power Baxter engines with 15-horse-power boilers, run by two of the soldiers of my command.

I would especially call your attention to the arrangement of the belting and shafting, which is so arranged as to obviate the use of an extension scaffolding to support the counter-shafting. The main shaft is *above* the counter-shafting, which is fastened to the side framing of the building directly beneath it; from this the driving-belts run obliquely to the machinery beneath. The gun-machinery, being belted from above, is placed next the main shafting; the cartridge-machinery is placed on a more distant parallel line driven by an oblique belt from the main shaft, and is belted to an underground shaft below it. This gives me the overhead space entirely clear. Instead of the long, unsightly overhead shipper-rods usually employed, all of my gun-machinery is provided with wire-cord connections with the counter-shafting. This runs over

pulleys, through grooves cut in the flooring, and by means of a wire spring on the counter-shaft shifts the belt with the greatest ease either on or off the loose pulley. These cords are so arranged that when the belt is on the driving pulley the spring is compressed, so that by simply loosening the cord the spring passes the belt to the loose pulley, instantly stopping the machine. In the arrangement of this machinery I have been greatly assisted by Mr. Jabez H. Gill and Mr. L. F. Bruce, my master-machinist. To Mr. Bruce I am indebted for the arrangement of the cord-shippers above described.

A series of boards contain every portion of the Springfield rifle in every stage of its manufacture, with the labels giving the name of the piece, that of the operation, that of the machine on which it is performed, and the number made per hour. Arms-chests packed with rifles and pistols complete the representation of the transition of the musket from its raw material to its condition of immediate issue. A box of standard cleaning-materials is shown.

Near by the main Government building is erected a Laidley iron-frame laboratory, which is the same one blown up in August last at the Frankford Arsenal. This is erected so as to show its panel construction, section of the panels being cut out to illustrate still further its design. Within this building is placed a collection of the electro-ballistic machines used in the United States service and the mercurial densimeter. These are operated by competent attendants, firing for this purpose reduced charges from the Springfield rifles. Incidentally is shown herewith the fixed rest, Ordnance Memoranda VIII, and the recoil dynamometer. The firing is done through a wrought-iron tube for safety. In order to obtain commensurable readings and to prevent any disagreeable shock to visitors, low charges of 12 grains are used. The range is 35 feet; the ordinary velocity about 450 feet.

A rifle prepared for the Rodman gauge illustrates the theory of gas-pressures, which is still further manifested by the exhibition of pressure-gauges of different kinds for cannon. The original apparatus for a similar purpose by Majors Bomford and Wade, 1842, and the Woodbridge oil-pressure gauge are shown in the section devoted to field-pieces, with the gun on which they were tried. This department is under the especial charge of First Lieut. C. W. Whipple, United States Ordnance, to whom I am indebted for its efficient maintenance. In it is a working-model of the target-recording apparatus, Ordnance Memoranda VIII, large enough for use by an inquiring visitor. A collection of inspecting-instruments for cannon, with the new star-gauge for rifled guns, is here exhibited.

The most interesting object of the exhibit, artistically speaking, is undoubtedly the model of Rock Island Arsenal, on the scale of $\frac{1}{300}$, prepared under my direction, by Baron F. von Egloffstein, New York, by means of the "photo-plastic" process, known also as "photo-relief" and "photo-sculpture." This consists in exposing a *positive* photographic view, of say, the end of a building, over a thick film of sensitized gelatine, covering a glass plate; the soluble, opaque portions of the gelatine are then washed out. The film is then swelled by a peculiar process, so as to magnify its differences of level, until a suitable relief is obtained. A plaster cast of the film then gives a permanent mold, from which many repetitions can be made. A successive series of these plaster views, taken from the different sides of a house, are mitered together at their edges, and when roofed in form an *absolutely perfect* reproduction of the house itself, every stone and crevice being represented. In the representation of the commanding officers' quarters there may be easily seen, with the naked eye, a lattice-work around the piazza, the slats of which, in na-

ture, cannot be much over two inches wide, thus giving lines about .006 in width. The model represents the middle part of the island between the main river and the branch known as Sylvan Water. Upon it are represented the shops, railroad, store-houses, officers' quarters, gardens, barracks, hospital, reservoir, stables, and fountain; office, lake, river, roads, fences, paths, bridges, and many actual representations of typical Rock Island trees. These trees I believe to be something new in model-making. They are prepared as follows: A frame of twisted wire is first prepared from a photograph of the tree to be represented, giving the proper shape and size to the main trunk, limbs, and many of the small branches; this is then repeatedly dipped in a hot solution of gelatine, being alternately powdered with comminuted gelatine, to give the light appearance of leaves, &c. It is then dyed to the proper tone and set in position. The water is made of a double thickness of fluted glass, laid crosswise and covered with a layer of plain glass. This overlies a tinted topographical representation of the river-bed, and makes the most natural water effect I have ever seen.

To protect the model from dust, handling, &c., it is covered with a case, the sides of which are of glass, three feet high. For economy, the top is of wood. As this darkens the model somewhat, I have provided a heliostat, moved by clock-work, which throws a stream of light upon a greater part of the model and produces a most picturesque effect by breaking up the ground-work with the shadows of trees, fences, and buildings. I believe this adaptation of the heliostat to be new and possibly of valuable application for the illumination of paintings ordinarily requiring a certain time of day to be seen at their best.

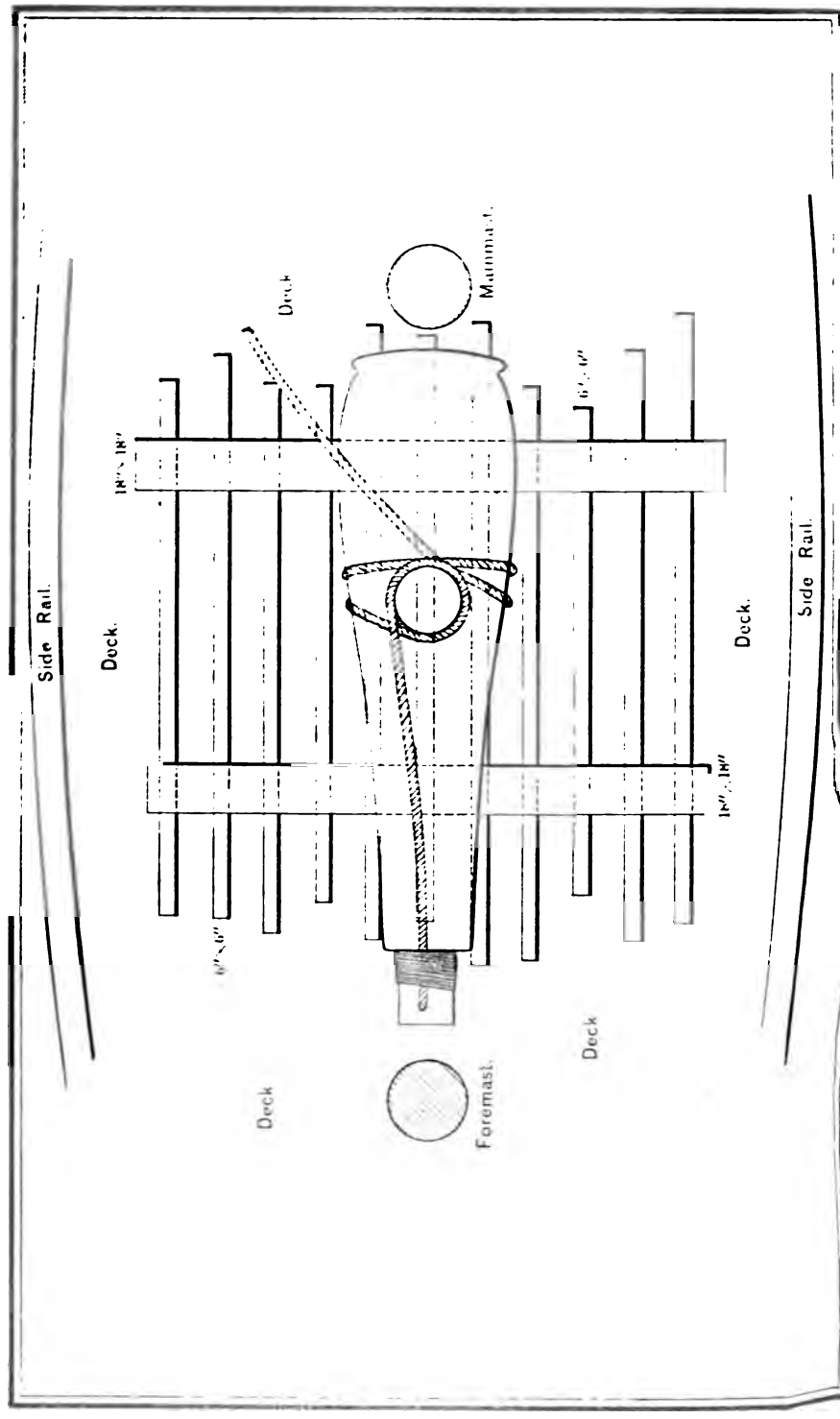
All attainable publications of the Department are freely exposed, and I am informed are frequently consulted by visitors.

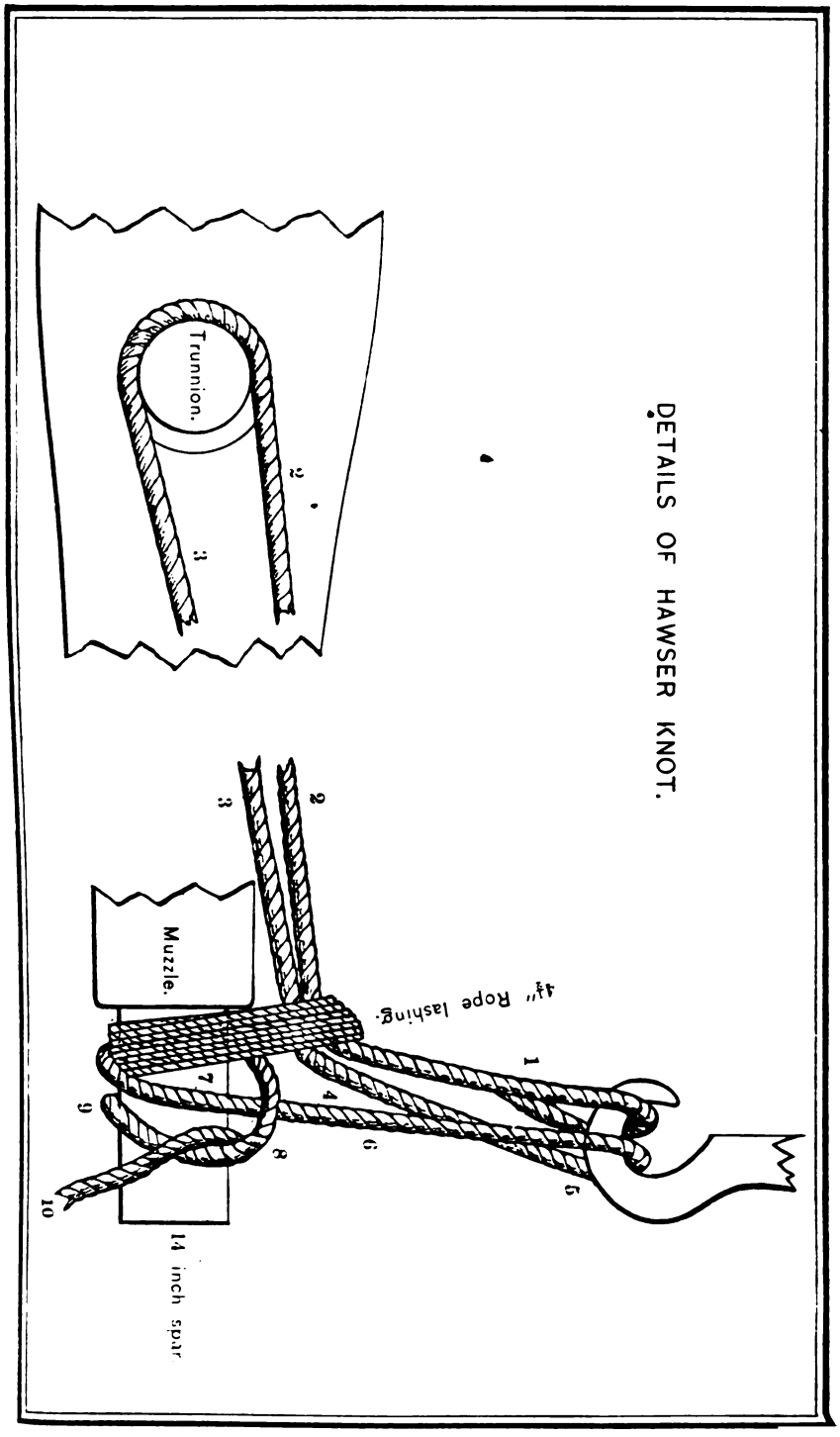
The decorations of the section comprise a large red and white banner, 10 feet by 12 feet, with the name of the Ordnance Department; two long pennants referring to the manufacture of cartridges and of the rifle, and a number of smaller pennants bearing the names of distinguished deceased officers of Ordnance. Above the line of small-arms is a thick-set *frise* of bayonets pointing inward, and at intervals are massed piles of gun-implements, equipments, sabers, pennons, and lances.

I have prepared a full descriptive catalogue of this exhibition, but as its size, estimated at 300 pages, printed, prevents its present publication from lack of funds, I am constrained to present herewith a copy of the index to the catalogue, with the hope that it may be printed and a sufficient number of copies be sent me for the use of visitors.

In the preparation of this exhibition, with one exception, I have had nothing especially worthy of note in this report. This exception refers to the unloading and mounting of the 20-inch gun. This gun, with a 13-inch sea-coast mortar of about 18,000 pounds, a cradle of say about 4,000, with heavy yellow-pine skidding and a deck-load of lumber, in all about 80 tons, was shipped to me from Fort Monroe on a vessel rated at 94 tons. She nearly foundered in a gale on Chesapeake Bay on her way to the canal at Baltimore, but arrived at this place afloat but leaking badly, with her deck only about eight inches above the water-line and about four feet below the level of the wharf at high tide. The steam-crane on the wharf had been found by analysis to be insufficiently strong to lift the gun entire, it was consequently simply used as an auxiliary. A 14-inch spar was wedged tightly into the muzzle of the gun and served as a fastening point for the 11-inch hawser by which the gun was raised.*

*The cuts on pages 38 and 39 show the position of the gun on the vessel and the arrangement of the lashing.


Side Rail.
Deck.
18" × 18"
6" × 6"
Deck
Mainmast.
6" × 6"
Deck.
Side Rail.
18" × 18"
Deck
Foremast.
Deck


DETAILS OF HAWSER KNOT.
Trunnion.
Muzzle.
4½" Rope lashing.
14 inch spar
1
2
3
4
5
6
7
8
9
10

The gun having been blocked up about 2 feet from the cascabel, at 4 p. m. on Friday, November 5, the crane began to lift. It lifted the muzzle about 15 inches, beside stretching the hawser about 8 feet. Blocking was then placed just back of the center of gravity of the gun, and the muzzle lowered on this pile as a fulcrum until the breech was high enough to take a fresh pile of blocking beneath it. By this lift the gun was raised about 3 inches. The position of the three supports was as follows: 1st, 5 feet from the muzzle; 2d, immediately back of the trunnions; 3d, 2 feet from the breech. Owing to the position of the third point, the crane was strained about 13 tons by this lift. Double piles of blocking were used at each bearing-point for safety, so as to limit any accidental fall in raising or lowering the gun to an inch or two at the utmost.

Chocking-quoins were also used to follow up the gun closely in its movements. About fifteen men were used throughout the maneuvers. One of these men, a ship-carpenter, with his adze and crosscut-saw, was particularly valuable. I had also a rigger from the United States navy-yard.

The hoists were made as follows:

No. of hoist.	Time.	Lift.	Remarks.
	P. M.	*Inches.*	
1	4.00	3.	
2	4.30	3.	
3	4.55	5.	
4	5.15	5.	15 tons on crane.
5	5.32	3	Took off the mortar with the crane and stopped work.
Saturday, November 6.			
	A. M.		
6	7.30	2.8	
7	8.00	2.25	
8	9.03	4.75	
9	9.31	3.	
10	10.15	2.25	
11	10.40	1.5	
12	11.35	3.25	Crane withdrawn from use by proprietor from 12.30 to 2.30 p. m.
13	2.30	2.25	
14	3.45	3.	It was observed that the muzzle had moved inward about 8 inches from the center line of the vessel, heeling the schooner considerably to port. This was corrected at 3 p. m. by a tackle fastened to side of the vessel, by which the muzzle was cut to a proper position. At 3.15 p. m., the breech having rolled slightly to port, it was rolled back an inch or two with pinch-bars.
15	4.07	7.	
Total.....	.....	57	20 tons on crane.

Heavy 18-inch yellow-pine skidding was then placed from under the gun to the wharf, inclining slightly upward, and the hawser parbuckled around the gun and fastened to the crane. A purchase was taken from

the muzzle by a locomotive standing on a neighboring track. The crane began to hoist at 6.44, the gun immediately rolling toward the wharf as the hawser uncoiled. The muzzle was cut meanwhile by the locomotive. At 7.04 p. m. the gun was landed, in 11 hours 6 minutes working-time.

As the vessel was relieved of the weight of the gun it rose, converting the inclined way of skidding into a declivity leading to the wharf. This feature permitted the pile of blocking on deck to be much lower than would otherwise have been necessary. On Sunday the gun was rolled by the crane and locomotive together to a position parallel with the railroad-track across which it had been necessarily landed. Toward the latter part of this operation the locomotive was dispensed with, it being found that by placing the crane in a favorable position, taking hold of the muzzle and then topping the boom, the muzzle could be cut almost as well as with the locomotive. At 11.55 a. m. the first lift was made to raise the gun to a sufficient height for loading on the platform-car; nothing could be done, however, until 1.50 p. m., the filling of the dock of coal-ashes, street-sweepings, &c., being so soft that whenever the weight was concentrated on the breech it would keep sinking as fast as the muzzle was raised. Finally, a wide platform was built under the breech, and the effective hoisting began at 1.50 p. m.; this was continued till 5 p. m., with the following result:

		Inches.	
1	1.50 p. m.	3.5	
2	2.00	4.0	
3	2.10	4.0	
4	2.20	4.0	
5	2.30	3.5	
6	2.50	4.5	
7	3.05	3.5	
8	3.25	3.6	
9	3.40	2.9	
10	4.00	2.5	
11	4.15	5.5	
12	4.20	4.5	Twenty tons on crane.
13	4.50	3.5	
15	5.00	4.5	
	2.30	54.0	

At 7.15 p. m. the gun was rolled to the car. At 8 o'clock it was on the car, on which it was transported safely the next morning to the exhibition grounds, and unloaded the same day. The advantages of my position in this operation were as follows:

I. The proximity of William C. Allison & Son's wharf and their large car-works, from which I obtained readily supplies of blocking, flat iron bars, heavy tools, men, and notably the use of their steam-crane and railroad-plant. I found the 6-inch oak car-bolsters especially valuable for blocking.

II. The use of an extra heavy flat car procured from the Pennsylvania Railroad Company.

The disadvantages were:

I. The small size of the vessel, its breadth of 23 feet giving only 8 or 9 feet on each side of the bare gun to work in. The gun also occupied all the space between the masts. With the additional weight of the blocking upon her decks used in raising the gun, the danger of breaking them in, or of starting fresh leaks was greatly increased.

II. The captain of the schooner refused to permit hydraulic jacks to be used for fear of breaking in his deck.

III. The gun had to be raised so high in order to roll it off upon the dock that the stability of the vessel was considerably endangered.

IV. The captain of the schooner refused to lie alongside the wharf, fearing shoal water; consequently, the gun had to be rolled off from the end of the wharf at right angles to the railroad-track.

V. I was obliged to do much of the work after dark in the hope of getting the gun on the car by Sunday, the Pennsylvania Railroad wishing to move it to the grounds on that day, for fear of obstruction to the track; otherwise I was liable to car-demurrage.

VI. The men were unaccustomed to moving heavy weights and shirked all they could, especially at night.

I was much assisted in this work by Messrs. A. B. Bury, of this place, and R. W. Baylor, now in my employ.

I have ventured to give this full account of the work of unloading the gun in hope that the difficult and somewhat perilous circumstances under which it was performed, and the novelty of some of the processes employed, may be of interest or of possible value.

In mounting the 20-inch gun, the Laidley gun-lift was used, assisted by blocking. The other guns were mounted with blocking only. The light auxiliary shears, provided with the Laidley gun-lift, proved of considerable value in placing in position heavy articles, such as the field-cannon, on the table spoken of, raising the ways of the drop-hammer, &c.

I also used a casemate-gin, mounted on three rollers. This was very useful in picking up heavy pieces, such as lumps of ore, drop-anvils, &c., and moving them to the pedestal or the foundation on which they were to be placed. Two of the rollers on the windlass-legs were joined together by a sleeve of heavy steam-pipe, fitting over the projecting limbs of the axles to prevent the rollers from assuming their natural position at right angles to the line of the leg.*

Very respectfully, your obedient servant,

HENRY METCALFE,
Lieutenant of Ordnance.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

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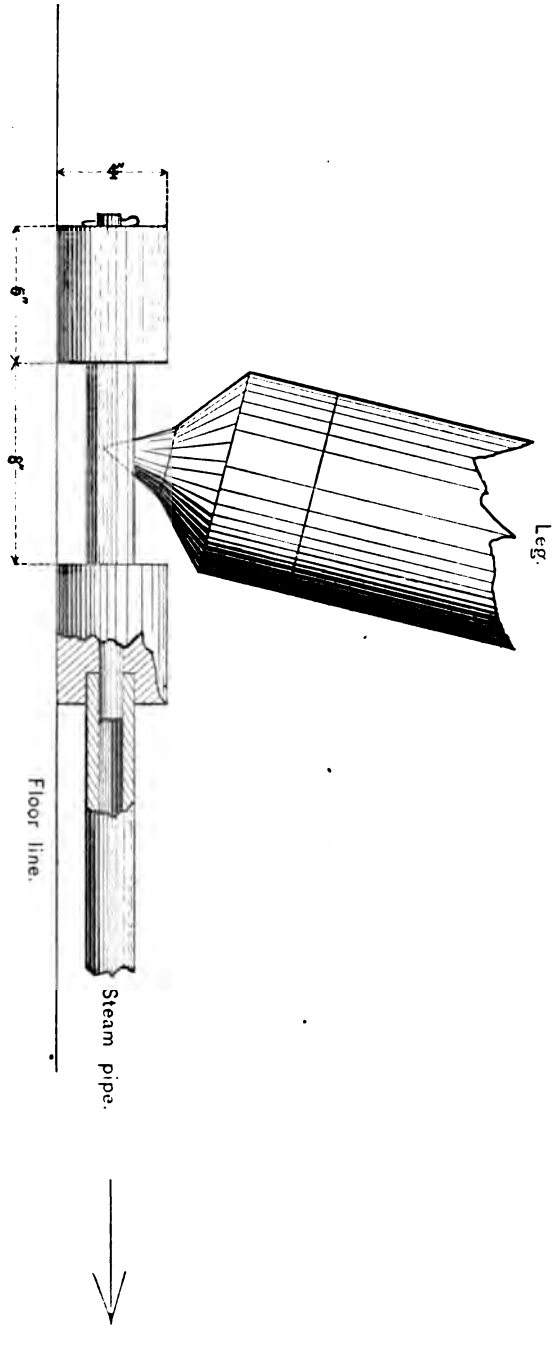
* See cut, page 43.



SKETCH OF GARRISON GIN ROLLER

APPENDIX G.

Artesian well at Benicia Arsenal.

BENICIA ARSENAL, CALIFORNIA,
August 22, 1876.

GENERAL: I have the honor to submit the following report of the work performed in boring the artesian well at this arsenal during the past year. The report, in reference to the actual progress obtained, is very discouraging; in reality, it is a detail of successive disappointments wrought by a series of accidents, all of which have been experienced by other well-borers; yet it is to be doubted whether all these reverses have ever characterized the work on any one well for the same short space of time in which they have occurred in this one.

The accumulative power of these failures has taxed the patience of all interested in the work, and, if other serious accidents had not previously occurred, and their results been rectified here, the effect of this year's work would have been very depressing on all our energies.

The Plutonic origin of this country, to which reference has been made in previous reports, forbids any one from making an hypothesis of future success which might be based on assured facts. The strata are upheaved in all directions, and, in some places, are nearly vertical, and the number and nature of the strata to be pierced before reaching a level at which a large supply of water can be obtained, are unknown.

The engineers in Europe who have completed flowing wells have commenced their work with the knowledge of the strata to be pierced, and the only unknown quantities for which they wished values were the depths of the different strata through which they had to work. It is otherwise in this country; boring for artesian water is a matter of pure experiment. No well here, except the one at Stockton and this one, can be regarded as furnishing real artesian water. The other wells are supplied with surface water, which falls on the mountains and hills, sinks through the soil until it reaches an impervious stratum, seeps down on top of this until it finds outlets through these bores, which vary from one hundred and fifty to three hundred feet in depth.

The oneness of supply of these different wells in the valleys of California is proved conclusively by the amount of water diminishing as the number of wells are increased in any one locality, and by the nature of the water they furnish.

You will perceive by this report that a partial success has been obtained, which secures to this arsenal a permanent supply of soft water, the use of which can be secured by placing a pump in the well 200 feet below the surface.

The fact of striking streams of water at two different depths, and the supply being larger from the lower source, induces us to entertain the hope that we will encounter a still larger supply of water at a greater depth. The water in this well has risen two feet above the surface, and could be carried higher if the pipe was extended upward, but the supply of flowing water is not sufficient, and the quantity can only be

increased by pumping 200 feet of water from the well, and thus relieving the water below of this pressure; it then seems to come in as fast as the pump can discharge it. As long as the bottom of the well continues in the present formation another subterranean supply of water may be opened at any time, which will flow over the top of the pipe in a sufficient quantity to relieve the Department of the expense of pumping.

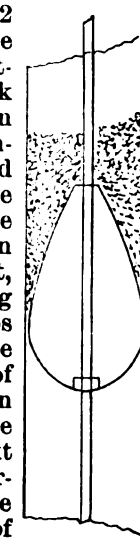
The report for last year gave the depth of the well on April 30, when work was suspended to make the new pipe, as 1,049 feet, of which distance only 960 feet were piped. The work of putting down the new 7-inch pipe was commenced in August, and 1,029 feet of it were inserted, the bottom of the pipe, on the 31st of this month, reaching within 23 feet of the bottom of the well-hole. Fifteen hundred feet of the new wire rope, manufactured with a zinc wire in the core, as described in the last report, was wound on the drum after having been well saturated with coal-tar. When the pipe was lowered, as described, and the wooden plug in the bottom of it driven out, the well-hole was found filled up 20 feet with caved rock, which was too hard to be removed by the pump. The drill had to be employed to loosen this *débris*, and to afford the pump an opportunity of doing its work in removing it.

The work in September commenced with this operation, and continued to progress slowly, but without accident, until the end of the month; the bore was at that time 1,078 feet deep, and was piped to within 12 feet of the bottom. The progress made this month through the solid rock was 28 feet and 7 inches, which amount of work was fair, considering the depth at which the tools worked. On the 29th of this month the pipe began to move very slowly under the pressure of the hydraulic pumps.

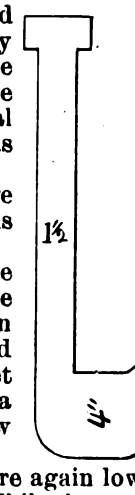
In October an increased depth of 14 feet 11 inches was made, and the pipe was inserted to a depth of 1,086 feet. On the 14th of this month it was ascertained, most unexpectedly, after pushing down the pipe, that the pump could not be lowered to a greater depth than 1,056 feet.

An impression was then taken of this obstruction, and the pipe was found crushed inwards at this depth. The most natural cause to produce this was presumed to be a piece of rock which had detached itself from the side of the well, on outside of pipe, and had worked its way down with pipe until it encountered a hard stratum into which it could not imbed itself, and was forced into pipe, crushing in its side. The projection on inside of pipe was so great as to lessen the diameter; so that, if this pipe was left in the well, the next one used, instead of being a 6-inch pipe, would have to be one of three inches diameter. In this case the use of six, five, and four inch diameter pipes would have to be resigned, and the chances of obtaining a much greater depth in the well reduced proportionally. An attempt was made to press out the pipe by using a shell at the end of the rods, an expedient which had proved effectual in straightening out the ragged ends of pipe and removing the flat surfaces of inner pipe; but in this case it proved useless.

After ascertaining, by several impressions on the kit machine, the exact nature of this accident and its effect on the pipe, it was determined to remove all the 7-inch pipe from the well. This pipe was in contact with the earth for a distance of only 126 feet, but weighed 11,946 pounds, and was wedged by this piece of rock so that it could not be moved up or down.



To effect this operation a pear-shaped block of maple, 2 feet long and 6⅝ inches in diameter, was inserted with base down, the rods passing through it and screwing into a left-handed square nut, which was let into bottom of the block to prevent it from turning. This method was adopted in hopes that, in case of an accident, or if it was found impossible to raise the pipe, the rods might be unscrewed from the block and extracted, and then the block could be broken up by the drill, and the well cleared, so that the water already obtained could be made available. On the 22d the block was lowered to a depth of 930 feet, and was fastened securely in that position by dropping gravel down the pipe on top of it. Two hydraulic pumps of 15 tons capacity each were applied, and the pressure gradually brought to bear on the rods at intervals of fifteen minutes all that afternoon and until midnight, when the pipe had apparently yielded one-eighth of an inch. The pressure was left on all night, and the same care used next day in increasing the pressure at intervals of time, but, during the forenoon of the 23d, the rods broke at a defective coupling, and 710 feet were taken out, leaving 220 feet of rods fastened to the block in the well.



A tool had to be manufactured to grapple the upper end of the system of rods left in the well, one by which they might be unscrewed from the nut at the bottom of the block. This was made, and an attempt commenced on the 27th with it, but it had to be twice altered, and several trials made, before a firm hold on the rods in the well was obtained.

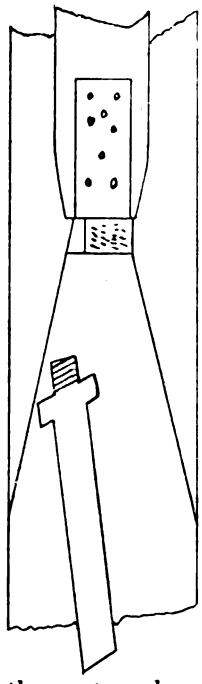
The power applied above, at the end of this long leverage of 925 feet, proved insufficient to unscrew the system of rods from the nut at the bottom of the block.

The upper system of rods was then removed from the well and carefully examined; no permanent set could be detected resulting from the twisting power which had been applied to them. Some of the rods were then tested, and it was proved that the rods would take a permanent set before twisting off or breaking the couplings, and that a much greater power could be used in the attempt to unscrew the lower rods from the nut than that already employed.

On the 13th the rods armed with the grappling-tool were again lowered for another trial, 740 feet of rods being employed. While the men were fishing for the lower rods, the upper coupling, high up in the tower, suddenly unscrewed by a twist in the rope, and 740 feet of rods fell with a crash to the bottom of the well. The two systems of rods filled the well-hole to within 223 feet below the surface. This second accident of course increased the embarrassment of the situation; but, as the course of action to be adopted was evident, no time was wasted in vain regrets. The object was to extricate this last system of rods from the well; the exact position of the upper coupling was ascertained, and the fact that it was perfect; therefore, if a female screw was used, it might be made to engage the male screw of this coupling, and facilitate the proposed work.

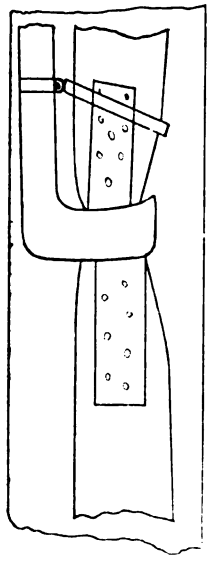
The only system of rods left above ground was that composed of wooden poles, and, as the strength required was thought simply to be

that necessary to raise 740 feet of iron rods, it was deemed expedient to make the trial with these.



The couplings of these poles were secured by pins or set-screws, so that they could not unscrew while they were in the well. These poles were used on November 3, the bottom coupling was readily screwed on the upper coupling of the rods in the well by means of a guide, made of sheet-iron in the form of a cone, fastened to the lower rod, which pushed the upper coupling of rods in the well so as to bring it in the center and just below the female screw coupling of the upper system of rods. The rapidity with which this was effected promised an easy solution to this difficulty, but on raising them, although the power was applied very gradually, they parted, leaving 59 feet fastened in the well screwed on to the system of iron rods. All the rods were now in the well, except the remainder of the wooden poles, and the upper one presented the fracture of a pole 3 inches in diameter and split for about a foot up along the grain of the wood. When the work was stopped this upper end was 164 feet below the surface of the ground.

The well-hole, which, before this accident, was regarded as filled, was now choked up, and nothing could be pushed down any lower than the above-mentioned distance. This situation of matters was extremely discouraging, and what men called "bad luck," and the Moslem "fate" seemed to be the lot of this well at the present juncture; for, if we could not extract the rods, the water already obtained would be lost to the Department. The lodgement of a tool in the well-hole was the accident which caused the Pacific Mail Steamship Company to abandon the idea of boring an artesian well which they had commenced here, and which had reached a depth of 300 feet. Of course, after the above failure, the wooden poles, as a means of extracting the others, could not be trusted, and new iron ones had to be made. The whole month of November was occupied in manufacturing these and a new claw-tool, by which a hold on the wooden poles could be obtained. It was also determined to increase the size of the iron, out of which both couplings and rods were made, and thus guard against any liability of breakage.



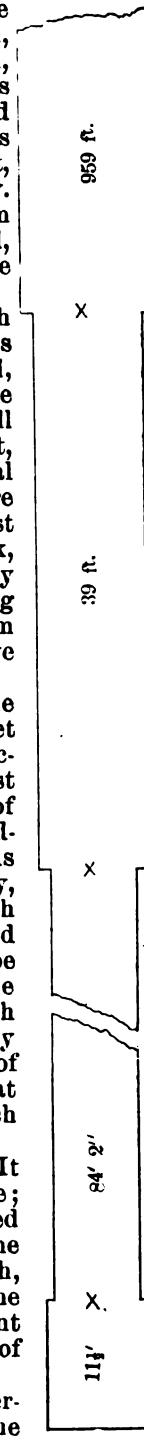
The new rods were made of 1½-inch square iron, which made them two and a quarter times stronger than the old ones, and the screws of the couplings were 2 inches in diameter. Set-screws for all these couplings were made, so that the latter could not be unscrewed until the former were removed. Two hundred and forty feet of these rods were manufactured, and on the 30th the work was resumed at the well. On taking an impression of the top of the broken rod in the well, it was found at a depth of 178 feet. Several trials were made with the claw at the end of the rods, but the tool, after taking hold of them, failed to maintain its grasp of the rods in the well. The grappling or claw-tool was then improved by placing an

iron ring, attached to its shank by a swivel, above the claw. This worked stiff enough to hold the ring horizontal, until it was passed over the head of the wooden pole, and, when the claw-tool got hold of the wooden pole by its coupling below and was pulled up, this ring was dragged down by the wooden pole pressing against the portion of its edge farthest from the shank of the tool in trying to slip out, and it thus held the pole from escaping from the claw below. It was then attempted to unscrew the wooden poles from the system of iron rods to which they had been screwed, but this caused a rupture of the lower coupling and the wooden rods were drawn out of the well.

The upper system of rods now in the well sank to a depth of 254 feet, and an impression of the broken coupling was taken at this depth. The same grappling-tool was used, and on December 4, a firm hold was obtained with it on the second set of rods in the well. By the 8th of this month all these rods were extricated, and, being found much bent, were taken to the shops to be straightened. An additional supply of the larger rods with the 2-inch couplings were then manufactured, as it was not deemed advisable to trust the 1-inch rods in the trial to raise the pipe. The block, having been so long in the water, had swollen so as not only to become a fixture in the pipe, but to bind the rod passing through its center; therefore, to unscrew these rods from the nut at the bottom of the block, which before might have been done, was now considered impracticable.

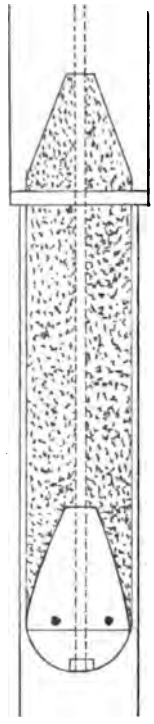
On the 3d of January the new rods were ready, and the top of the rods still in the well had sunk down to 738 feet and 4 inches from the surface of the ground. Several successive trials were made to grapple these, and on the last the rods were raised 14 inches; but one of the prongs of the claw-tool broke. A new tool was finished by the middle of this month, and on the 18th it grappled the lower rods and they were raised 18 inches. When, on the next day, they had been raised 25 inches the pipe began to move with rods, and on the 22d 27 feet of it was freed from the well and disconnected. During the following week 148 feet of pipe were raised. Work was continued successfully, and on the 12th of February the claw-tool and commencement of 1-inch square iron rods appeared above the mouth of the well. By the 15th all the pipe which held together was taken out of the well with the wooden block, and it was ascertained that there remained still in the well 84 feet 2 inches of the 7-inch pipe.

The condition of the well at this time was as follows: It was piped 959 feet from the surface with the 8-inch pipe; then there was a space below this of 39 feet in length bored to a diameter of 7½ inches without any pipe; and then the 7-inch pipe, which was 84 feet and 2 inches in length, reached to within 11½ feet of the bottom of the well. The problem to be solved was, how to get hold of this remnant of 7-inch pipe and raise it, through the 8-inch pipe, out of the well.



There was a difficulty in effecting this which did not appertain to the first trial to raise this pipe. In that case the

gravel to tamp the block and keep it in its place was poured in from the top of the pipe, which was above the surface of the ground. This method could not be used now, as the gravel, if poured down the 8-inch pipe, after having fallen through it, would not only fall into the 7-inch pipe, but outside of it, and fill up the space around the pipe, between it and the wall of the well, fastening the pipe in the well, and preventing effectually the result desired to be obtained. To obviate this difficulty it was determined to send down a load of gravel with the block by using an iron cylinder which should retain its load until the block was in the lower pipe, and then, by some automatic contrivance, allow it to escape in that pipe only and to spread itself over the top of the block. An iron cylinder, with conical top, 6 feet long and 6⅝ inches exterior diameter, was made and fastened to the top of the block with four wood-screws. On the outside top of the cylinder part a ring of forged iron was riveted, the exterior diameter of the ring being 7⅝ inches. The block was fastened to rods, the cylinder screwed to it, and the latter filled with gravel. This system was lowered through 8 inch pipe and the space below it, and the block and cylinder passed into 7-inch pipe; but the wrought ring caught on the upper edge of it and retained the sheet-iron cylinder there, while the block continued to descend into the pipe, tearing out as it went down the wood screws which fastened the cylinder to it, and freeing the bottom of the latter so that the gravel followed the block into the pipe, spreading through it and covering the top of the block. On hoisting the rods it was found that a firm hold on the pipe had been obtained, and no further difficulty was experienced in raising it. By the 25th of February all of this pipe was out of the well and the bottom of it was freed from every foreign substance. The conjecture made in reference to the cause of this accident when it occurred was proved correct, as a hole was found in the pipe 7 feet and 6 inches from the bottom of it, made by the piece of rock. The pipe had to be repaired, as well as the tools, and the work at the well was delayed until March 27.



As no news of a further appropriation for continuing the boring of the artesian well had been received at this time, it was determined, before putting down the 7-inch pipe again, to ascertain the supply of water which the well in its present condition could furnish, and, if it proved sufficient to justify the expense, to retain a sum of money from the present appropriation which would enable us to make all the arrangements necessary to pump the water into the reservoir on the hill.

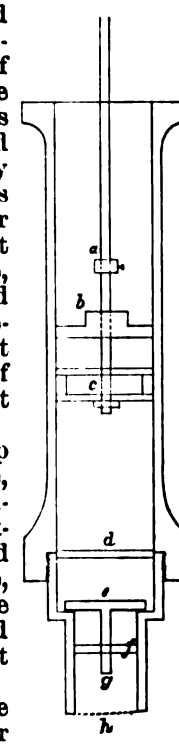
A deep-well pump was made, with an interior diameter of 3½ inches and a 3-feet stroke. This was connected with a wrought-iron 4-inch diameter pipe, and was lowered 200 feet into the well.

On the 28th of this month the lever which was worked by the steam-cylinder was attached to the rods which worked the piston of the pump, and at 11 a. m. the pump was started and the work was continued until 11½ p. m., a period of twelve hours and a half, when the rods unscrewed. The pump was lowered again on the 30th and worked from 1 p. m. to 2 p. m. on the following day, a period of twenty-five hours.

In both the above instances the pump furnished 1,400 gallons of water per hour, until the well was emptied down to the pump; then it continued to discharge uniformly 900 gallons an hour, and the flow of water equaled this when the pump was stopped. It was estimated that if the

pump was used in the well every other day, for eight hours, it would furnish each day at least 9,200 gallons of water, and if it was used every day the supply would be 8,300 gallons of water.

On the 5th of April the work at the well was resumed by lowering the repaired 7-inch pipe, and this was continued until the 27th of the month, when 1,054 feet of well had been successfully piped. On the next day the pipe stopped and would go no further; the cause of this was sought for in vain in the pipe; the gauge passed easily to the bottom through the pipe, and the only cause for this stoppage which could be imagined was that either the side-cutters had not performed their work properly, and that the bore of the well below it was not large enough to permit the passage of the pipe, or that the *débris* from the cave had collected around the outside of the pipe and wedged it. After some deliberation it was concluded to raise the pipe 10 feet and thus allow the *débris* to escape into the bottom of the well, or, if the bore was found too small, to ream it out to the proper size.



a, nut to keep upper valve from rising.
b, upper valve sliding on rods.
c, hollow piston.
d, diaphragm to keep lower valve from rising.
e, lower valve.
f, bar to keep valve vertical.
g, guide for lower valve.
h, copper strainer.

The same process of using block with gravel on top of it, as heretofore used, was employed with confidence, as the large iron rods we now had precluded any accident from breakage. After raising the pipe it was expected to push the block down through the pipe and allow the gravel to escape into the well below the pipe, and then to raise the block through the pipe out of the well; on May 2, the block was put down and a hold obtained and the pipe was raised 11½ feet, a sufficient distance to effect our object.

As the block had only been in the water a short time and was three-eighths of an inch smaller in diameter than the pipe, we hoped that it had not increased sufficiently in size to fill the latter, and expected the weight of the rods alone to force it to the bottom of the well, but on trial the block would not go down, having swollen tight in the pipe.

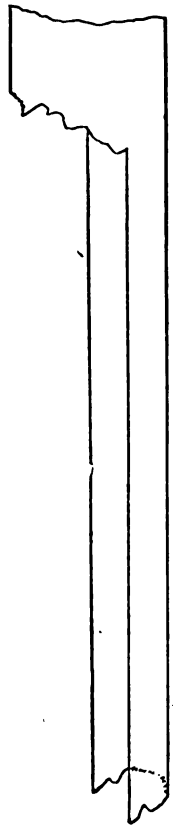
There was a slide attached to the ends of the rods, just over the block, of 2 feet, and, by raising the rods this distance and allowing them to fall, a great force could be applied to the block. It was, however, unnecessary to use this height, for three strokes of the rods, raised on each occasion a few inches, drove the block, as was thought, through the pipe to the bottom of the well and released the gravel. We commenced then to raise the block out of the pipe, intending, when this was accomplished, to ream out the bore of the well below the pipe.

This was done successfully, but required much more force to effect it than was deemed would be necessary. On the 4th of May, after the block was taken out of the well, the pump was lowered and then the gauge, but neither could be pushed to the bottom; both stopped at a distance of 945 feet from the top of the pipe. Further examination proved to us that we had experienced another misfortune, as the pipe below was broken and telescoped, but the cause of the disaster could not then be definitely ascertained.

There was no alternative left but to take all the pipe from the well a second time, unless we concluded to resign the use of this 7-inch pipe,

and to smooth down the interior, and commence to use a new pipe of 6-inch diameter.

In raising the pipe it parted in several places, and had to be taken out in sections of various lengths. By May 23 all the sections of the pipe above 970 feet from the surface down were extricated from the well. It was found that the last portion of this pipe, 17 feet in length, was robbed of half its proportions, its cross-section forming but half a circle, and its edges appearing as if the pipe had been cut vertically with a pair of shears for the above distance, while the lower edge of this fractured part was rough and jagged, and indicated clearly that the pipe had been torn or twisted off by the application of great force. Of course the upper 17 feet of the pipe in the well must correspond with the bottom of this pipe, as it was cut from it.



A hook was now made to take hold of the iron ring at the bottom of the pipe; it was attached to the rods and a hold was obtained with it to raise the pipe, but in the effort to accomplish this the hook was straightened. Another of heavier metal was manufactured, and on May 30 the pipe was raised until the top of it touched the bottom of the 8-inch pipe. The next day the pipe was raised from the well, and the upper portion of it was found to be split vertically for 27 feet.

It was quite remarkable that the lowest 40 feet of pipe, armed with the steel ring at the bottom, was taken out perfectly uninjured and was ready for use, but three intermediate joints, between the bottom and top, and some broken pieces of pipe, were missing, and were found afterward at the bottom of the well.

It was thought when the block went down that it was free from the pipe, but in this supposition we were mistaken, for, when the rods were allowed to fall down the slide on the block to free it from the pipe, it being immovable, the blow created a sudden strain on the pipe, which parted some rivets about 64 feet from the bottom, and it was afterward ascertained that the block and a portion of the pipe went down the well together. Then, when the rods were withdrawn, this piece of pipe was forced up with the block, its edge against the upper pipe, and, the iron of which it was made being too weak to raise this last-named pipe, cut through both itself and the upper pipe.

After getting out these broken sections of pipe the 8-inch pipe was found to be perfectly clear, the shell at the end of rods passing through it easily. Attempts were then made to raise the few remaining fragments of pipe in the well, but they were found too weak to be drawn through the 8-inch pipe. When they were raised to the bottom of this they broke off, as they could not resist the force necessary to make them enter it.

Up to this date we had heard nothing of any new appropriation to continue the work at the well, and as there was a balance left of the money on hand from last year's appropriation, it was considered prudent to make every arrangement necessary to enable the Ordnance Department to use the water already obtained. In order to effect this, 500 feet of 3-inch wrought-iron pipe was purchased and laid, reaching from artesian well to main pipe leading to the resevoir on top of the hill.

The deep-well pump was put down 200 feet into the well and connected with the lever. The pump was kept working eight hours, and delivered

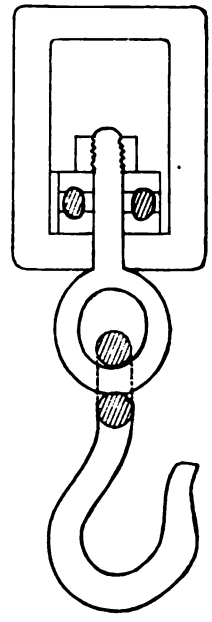
on top of the hill 15,000 gallons of water, and when the work was stopped, the quantity of water discharged per minute had not perceptibly decreased. This, with the former trials, was considered a satisfactory test of the ability of the well, engine, pump, and machinery to furnish a sufficient quantity of soft water for the use of this arsenal.

We then resumed our former work at the well. The pipe was overhauled and repaired and 40 feet of new pipe made, which was placed immediately above the steel ring with which the bottom of the pipe is armed. The foundation of the steam-cylinder was renewed and the cylinder itself repaired.

As soon as we hear that an appropriation for continuing the work has been passed and approved the 7-inch pipe will be lowered into the well; and, as this will be the third trial with it, we hope it will also be the last and prove successful.

Before closing this account of the work done at the well it is but fair to mention the fact that Captain Clifford invented a swivel to connect the flat-wire rope with the top of the rods; and, as it has answered this purpose much better than any swivel used before, a description of it will not be out of place in this report.

It was composed of a frame, eye-bolt, hook, and nut, all of which were of iron, and two plates and fourteen balls made of steel. The revolving motion was given to the eye-bolt by the rolling motion of the fourteen cast-steel balls, which worked in two grooves, one in a lower and the other in an upper steel plate. These plates were assembled and held together by the eye-bolt, the eye of which was close against the bottom of the frame, and the bolt passed up through them and held them tight by means of a nut screwed on to it above upper plate.



The accidents experienced and overcome this year have been of a very serious nature and of frequent occurrence, but, even when the well was in the most precarious condition, hope of ultimate success has never abandoned those engaged in the work. By patient toil all effects of these accidents have been rectified, and none of them can be considered due to want of judgment.

Without presumption the Department can congratulate itself that it has accomplished, on this coast, in two months, the work which occupied the engineers at the well of Passy, in France, more than a year. The above-mentioned well was commenced in July, 1855, and by constant work, in seventeen months, say in December, 1856, it had reached a depth of 528 meters, when the pipe accidentally was crushed in while passing through the clay stratum. This circumstance delayed the work, and the well was considered a failure by the mining-engineers generally.

A German well-borer, after overcoming great difficulties, succeeded in rectifying the effects of this accident and continued boring until May 25, 1861, nearly five years after its commencement, when, at a depth of 576 meters, water was obtained.

It took, therefore, four years and three months to overcome this difficulty, and to deepen the well 48 meters. The water obtained at this depth did not rise to the surface, but remained three meters below it. On the 24th of September of the same year, that is, four months after-

ward, a second water-course was struck, and the water from this rose 24 meters above the surface, and furnished 1,300 cubic meters of water per hour.

The work at this arsenal compares favorably with the above in extent and in the time occupied, and has cost much less.

I am, general, very respectfully, your obedient servant,

J. McALLISTER,
Lieutenant-Colonel Ordnance, Commanding.

The CHIEF OF ORDNANCE,
Washington, D. C.

APPENDIX H.

Report of Lieutenant-Colonel Silas Crispin, Constructor of Ordnance, United States Army.

OFFICE OF CONSTRUCTOR OF ORDNANCE,
New York City, September 25, 1876.

SIR: I have the honor to inclose herewith reports on the construction of the following-named ordnance, to wit:

Thompson 12-inch breech-loading rifle.
Sutcliffe 9-inch breech-loading rifle.
Converted 8-inch muzzle-loading rifle No. 1.
Converted 8-inch muzzle-loading rifle No. 2.
Converted 9-inch muzzle-loading rifle No. 3.
Converted 9-inch muzzle-loading rifle No. 4.
Mann's 8.4-inch breech-loading rifle, altered from 8-inch.
Moffatt 3.07-inch breech-loading field-gun.
Sutcliffe 3.15-inch breech-loading field-gun.

The above comprises (except the Moffatt 6-inch breech-loading, flank-defense howitzer) all the experimental guns which have been constructed under the supervision of this office up to date.

In order to present a connected history of the converted guns, some matters heretofore submitted had to be introduced in the reports of their construction.

I am largely indebted to the services of Capt. J. G. Butler and Lieut. C. S. Smith, of the Ordnance Department, in the compilation of these reports from the data on the files of this office.

Very respectfully, your obedient servant,

S. CRISPIN,
Brevet Colonel U. S. A., Lieutenant-Colonel of Ordnance, Constructor of Ordnance.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

HISTORY OF THE CONVERSION OF 10-INCH SMOOTH-BORES INTO 8-INCH AND 9-INCH RIFLES.

The lining of a cast-iron body with a steel tube, as a system of construction for rifled guns, (10-inch and 12-inch,) was recommended for trial by the ordnance board convened under the order of the War Department, dated December 17, 1867. Subsequently, in a communication from this office to the Chief of Ordnance, dated June 12, 1872, specific inventions in gun-conversions, by lining our existing smooth-bores with rifled tubes of steel or wrought iron, were recommended for trial, in order to see if the large number of comparatively ineffective smooth-bores, constituting the casemate armament of our sea-coast defenses, could be utilized by conversion into rifles; and also to throw as much light as possible upon the system *per se*, in its relation to higher calibers of original constructions.

A 10-inch Rodman smooth-bore was recommended for conversion, and the caliber of the tube to be 8-inches or 8½ inches.

This communication was submitted by the Department to the board

on "heavy-rifled ordnance," instituted under the act of June 6, 1872, for the selection of breech-loading and muzzle-loading rifled ordnance for experiments and tests; and among other experiments recommended by that board was the following:

"That in order to test the system of gun-conversion by lining with steel and wrought-iron tubes, (as brought to the notice of the board in a communication addressed to the Chief of Ordnance by Major S. Crispin and referred to the board by the Ordnance Department,) four 10-inch Rodman smooth-bore guns be converted to muzzle-loading rifles, using two calibers; two of the guns to have a caliber of not less than 8 inches, and two to have a caliber of not less than 9 inches; and further, that two of the guns be converted by tubing from the rear and two by tubing from the front; the character of the metal lining, whether of steel or wrought iron, and other details of conversion, to be determined by the War Department."

The recommendation of the board in this regard having been approved, a board of ordnance officers was convened under orders from the War Department, dated Washington, September 18, 1872, "to recommend the place, manner, and details of the construction of the heavy guns selected by the board on heavy rifled ordnance."

Touching the converted guns, the board recommended as follows:

"That in the conversion of the four 10-inch smooth-bore Rodman guns recommended by the board on heavy ordnance, organized under the act of Congress, approved June 6, 1872, for experiments and tests, that two be made of a caliber of 8 inches, one tubed from the front, and one from the rear; and two of a caliber of 9 inches, one tubed from the rear, and one from the front; that the dimensions and details of construction be as given in the drawings appended; that the guns be altered at the West Point or South Boston foundry, as may be determined by the Chief of Ordnance; that the tubes be made in Europe at establishments competent to do the work; and that the supervision of the conversion be intrusted to some officer or officers of the Ordnance Department, to be selected for the purpose by the Chief of Ordnance."

The drawing accompanying the report of the board, and adverted to above, specified that one tube of each caliber should be of steel re-enforced with a jacket, and inserted from the rear; and that one of each caliber should be of wrought iron and inserted from the front. The determination of the details of rifling and venting, of the character of the powder and projectiles, and the carriages to be provided for the trial of the guns, was the duty devolved upon the ordnance board, convened under orders from the War Department, dated March 29, 1873. The decisions of that board, in the above respects, were, however, more or less modified subsequently by the resolutions of the board on experimental guns, &c., convened under orders from the War Department, dated October 10, 1874.

The West Point foundry having been selected by the Department as the place of fabrication of the converted guns, this office was intrusted with the supervision of the work, and directed to enter into the necessary arrangements with the foundry company for its prosecution.

Four 10-inch Rodman guns having been shipped to the foundry, specific instructions were furnished as to the mode of boring them up and inserting the tubes. The order of conversion it was decided should be as follows, viz:

First—8-inch wrought-iron tube.
Second—8-inch steel tube.
Third—9-inch wrought-iron tube.

8 INCH RIFLE No. 1 converted, wrought iron tube.

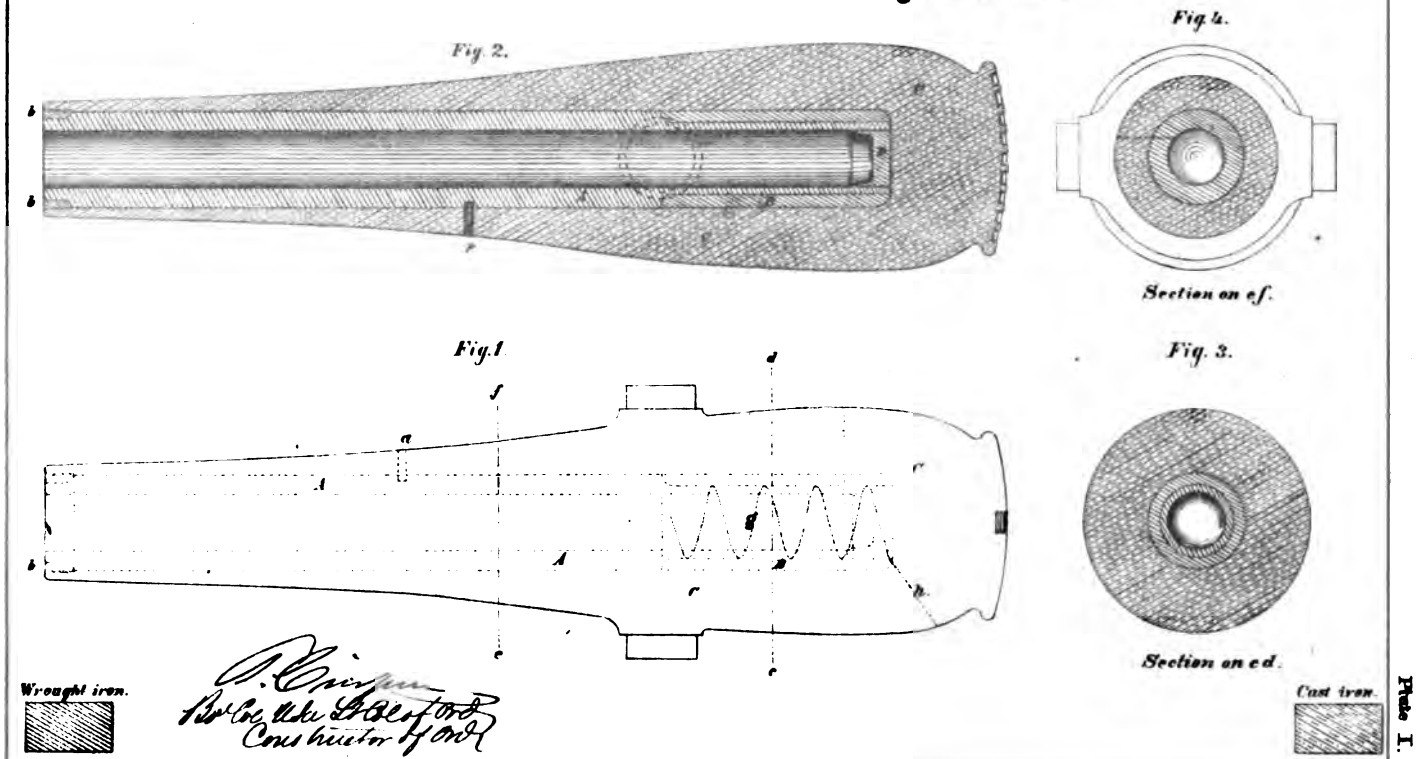


Plate I.

Fourth—9-inch steel tube.

The 8-inch guns were finished in the month of October, 1874, and were removed to Sandy Hook for trial under the direction of the board on experimental guns, &c.

The 9-inch gun, wrought-iron lined, was finished and sent to Sandy Hook in November, 1875; and the 9-inch steel-lined in March, 1876.

EIGHT-INCH RIFLE No. 1, CONVERTED—WROUGHT-IRON LINED.

Description of the gun.

Plate I, Fig. 2, C is the cast-iron body of the gun, consisting of a 10-inch Rodman smooth-bore, bored up to a diameter of 13″.5 for the reception of the lining-tube A, of coiled wrought iron, the breech of which, to a distance of 32″.75, is a double tube.

The outside, or B tube, is shrunk upon the inner, or A tube, with 0.003 of an inch shrinkage in the diameter, the latter having been reduced in diameter, through a sufficient length, for its reception. The bottom of the tube is closed with a wrought-iron cup, D, screwed into the A tube, the threads on the A tube projecting beyond the surface of the tube. The exterior diameter of the tube is such as to allow a minute play between the tube and casing, not exceeding 0″.015 from the muzzle to a point 32 inches from the bottom, and not exceeding 0″.007 through the remaining length of the tube, the object of which is to permit the free insertion of the tube. This play is afterward absorbed by the setting out of the tube under firing. The tube is inserted into the casing from the muzzle, and is secured from working out by the muzzle-collar *b*, and is prevented from twisting in the casing by the steel pin *p*, tapped through the casing and into the tube.

A spiral gas-channel Fig. 1, *g*, 0″.05 deep, and 0″.1 wide, is cut around the exterior of the reduced portion of the A tube, which communicates with star-grooves cut in the end of the barrel, and the gas-escape, or indicator *h*, bored through the breech of the casing.

Should the inner tube split under the action of continued firing, the fact would be indicated by the escape of gas through the indicator-hole, and timely warning thus be given of the injury sustained by the gun.

The curved part of the end of the tube is described with a larger radius than the corresponding curve in the cast iron, so as not to be in contact with it at that part. This space prevents the tube from acting as a wedge to split open the cast iron.

The thread upon the muzzle-collar slightly exceeds in length that of the corresponding thread in the muzzle of the casing, so as to insure a close contact between the end of the tube and the bottom of the bore of the casing.

RIFLING.

The rifling of the gun consists of fifteen lands and grooves, each of equal width.

	Inch.
Width of lands and grooves	0.8377
Depth of grooves	0.075

Twist uniform, one turn in 40 feet.

As is the case with all the service muzzle-loaders, there is no chamber proper to the gun. The rifling stops at a point 10 inches from the bottom of the bore, and the diameter of the unrifled portion of the bore is equal to that of the rifled portion across lands.

VENTING.

The old vent was closed (the copper bushing having been removed) by a wrought-iron screw-plug, and 2″.75 nearer the muzzle, a new one was bored, parallel to the vertical plane through the axis of the bore, and distant therefrom 2″.50. The axis of the vent enters the bore at 3″.5 from the bottom.

FABRICATION OF THE GUN.

The gun selected for this conversion was a 10-inch Rodman smooth-bore, manufactured at the South Boston foundry in 1866, and inspected and proved in that year.

The density and tenacity of the metal were as follows: density, 7.2722; tenacity, 32,370 pounds, and the initial tension 12,000 pounds.

The tube inserted in this gun was of coiled wrought iron, and was manufactured at Sir William Armstrong's works, at Newcastle-upon-Tyne, England. Specimens of a bar-iron, similar in quality to that used in the manufacture of this tube, were furnished to this office and tested here with the following results: mean density, 7.6905; mean tenacity, 52,533 pounds.

Tables 2 and 3, appended, show the extension, restoration, and permanent set, under a gradually increasing strain.

The tube, when received, was bored to an interior diameter of 8 inches, the true caliber of the gun, but was left with an excess of metal on the exterior over the prescribed diameter, in order that it might be turned down to fit the cast-iron casing. The fabrication of the tube was after the method usually pursued by the English, the various operations of which are generally described in the "Text-Book of the Construction of Rifled Ordnance," as follows:

"The coils for the tube are made of bar-iron specially prepared by being put three times through the roughing-rolls. The tube is formed of fine coils united together in the usual manner, and is rough and fine bored to something less than the required diameter, and the recess in the breech cut and tapped for the wrought-iron cup. The cup for closing the breech-end of the barrel is forged and stamped into shape under a steam-hammer. It is turned inside and out, and screwed on the outside with a thread of five to the inch. It is then screwed tightly home. The tube in this state is proved with water-pressure of 120 pounds on the square inch, to ascertain that the cup fits tightly and that there is no leakage. The breech-end of the inner or A tube is then turned over a length of 32 inches for the outer or B tube, previously bored, and a spiral gas-channel 0″.05 deep and 0″.1 wide is cut round the exterior, communicating with the star-grooves cut in the end of the barrel, and the gas-escape through the cast-iron breech. The B tube consists of two coils united, and being rough-turned on the exterior, and finished bored to 10 inches, it is shrunk on with 0″.003 shrinkage in the diameter. The whole tube is then rough-turned, and the bore broached to 8 inches and examined, after which the exterior is ready to receive the final turning to fit it to the cast-iron casing."

The cast-iron body of the gun was bored up as nearly as possible to a diameter of 13″.5, and the indicator-hole bored through the breech. Careful measurements at intervals of 1 inch showed that the bore varied in diameter only 0″.001 from breech to muzzle, with an average diameter of 13″.496. After these measurements were obtained, the tube

was placed in a lathe and turned to a diameter of 13″.486 throughout, which allowed a play of 0″.01 between the tube and casing.

The tube being now ready for insertion, it was oiled and then wiped, and the breech-end smeared with red lead. It was then lifted by a crane, swung round in front of the muzzle of the casing, and inserted as far as the slings would permit; the slings were then removed, and a block and tackle attached to the muzzle, by means of which the tube was forced "home" under a moderate pressure. After being well worked in the casing, the tube was withdrawn to ascertain if the breech-end had an even bearing on the bottom of the casing, a fact which would be clearly indicated by the red lead. This important point having been satisfactorily established, the tube was wiped, and again inserted and forced home. The muzzle-collar was then screwed in, and the steel pin inserted through the casing; after which the muzzle was faced, the bore lapped and rifled, the old vent closed, and a new vent nearer the muzzle bored and bushed with copper.

INSPECTION.

In addition to partial inspections made during the progress of the work, a final inspection was made upon the completion of the gun, in which the general workmanship and finish were carefully examined. The gun was accepted as satisfactory.

Principal dimensions.

Subject of measurement.	Dimensions.	
	Prescribed.	Actual.
Total length of tube	120″.	120″.
Total length of bore of casing	120″.	120″.
Diameter of bore across lands	8″.	7″.985
Diameter of tube finished from breech to muzzle	13″.493 to 13″.485	13″.486
Mean diameter of bore of casing	13″.5	13″.496
Length of jacket	32″.75	32″.75
Interior diameter of jacket	10″.	10″.
Diameter of tube under jacket	10″.003	10″.003
Shrinkage	0″.003	0″.003
Depth of gas-escape	0″.05	0″.05
Width of gas-escape	0″.10	0″.10
Pitch of spiral of gas-escape	8″.	8″.
Length of bore	117″.25	117″.25
Length of neck of tube under muzzle-collar	3″.75	3″.75
Length of muzzle-collar	3″.75	3″.75
Length of recess in casing	4″.4	4″.4
Length of screw part of muzzle-collar	2″.90	2″.90
Length of screw part of recess in casing	2″.775	2″.775
Excess in length of screw over that in recess	0″.125	0″.125
Diameter of tube across neck	12″.	12″.
Interior diameter of muzzle-collar	12″.01	12″.01
Diameter of muzzle-collar across threads	14″.	14″.
Diameter of recess in casing	14″.01	14″.01
Thickness of collar	1″.	1″.
Pitch of thread on collar	0″.5	0″.5
Length of rifled portion of bore	107″.25	107″.25
Depth of wrought-iron cup at bottom of tube	2″.75	2″.75
Thickness at bottom of wrought-iron cup	2″.75	2″.75
Diameter of cups on threads	7″.8	7″.8
Pitch of thread on cup	0″.2	0″.2

Principal dimensions—Continued.

Subject of measurement.	Dimensions.	
	Prescribed.	Actual.
Width of grooves	0″.8377	0″.8377
Width of bands	0″.8377	0″.8377
Depth of grooves	0″.75	0″.75
Pitch of rifling	40 feet.	40 feet,
Diameter of vent	0″.20	0″.20
Diameter of vent-bushing	1″.	1″.
Axis of vent from bottom of bore	3″.50	3″.50
Axis of vent from vertical plane through axis of bore	2″.50	2″.50
Distance of securing-pin from muzzle	60″.	60″.
Length of securing-pin	5″.12	5″.12
Diameter of securing-pin	1″.50	1″.50
Weight of gun	16,160 pounds.	
Counter-preponderance	630 pounds.	

NOTE 1.—On Plate V are shown the projectiles used in the trial of the gun. Fig. 1 the Butler, and Fig. 2 the Arrick, are described in the report of the Ordnance Board on the trial of the gun. (See Report of the Chief of Ordnance for 1875.)

Fig. 3, the Dana projectile, consists of a cast-iron body, A, having a conical base, to which is attached a cup-shaped ring, C, of brass. Upon discharge the ring is driven forward upon the base, and by this movement the soft metal is expanded into the grooves and rotation communicated to the projectile. As the front end of the sabot passes the shoulder F, it is crowded down into the groove B, cut round the body of the shot, and thus "clinched," as it were. The same end is sought in the arrangement at the bottom of the sabot, where the gas acting in the cannelure D, presses the lip into the groove E cut in the cast iron. Such is the provision designed to secure the sabot from stripping. Turning upon the projectile is prevented by wedge-shaped projections and recesses upon the base of the projectile and the under surface of the sabot. Prescribed weight of cored shot, 180 pounds.

NOTE 2.—For description of carriage, see report of the Ordnance Board on the trial of the gun, in Report of Chief of Ordnance, 1875.

Experiments and tests.—This gun has been fired at Sandy Hook under the direction of the Ordnance Board, in all 761 rounds. The record of the first 700 rounds forms part of the reports of the Ordnance Board of the trial of the gun, published in the Annual Report of the Chief of Ordnance for 1875.

Sixty-one rounds additional have been fired since those reports were made, and the gun is still in a sound and serviceable condition.

This gun is now on exhibition at Philadelphia.

TABLE No. 1.

Relative diameters of bore of cast-iron body of 10-inch gun and wrought-iron tube for insertion therein at different points of their cylindrical length.

Inches from face of muzzle.	Interior diameters of bore.	Exterior diameters of tube.	Difference.	Inches from face of muzzle.	Interior diameters of bore.	Exterior diameters of tube.	Difference.
118	13.4965	13.4860	0.0105	76	13.4965	13.4860	0.0105
117	13.4965	13.4860	0.0105	74	13.4965	13.4860	0.0105
116	13.4965	13.4860	0.0105	72	13.4960	13.4860	0.0100
115	13.4965	13.4860	0.0105	70	13.4955	13.4860	0.0095
114	13.4965	13.4860	0.0105	68	13.4955	13.4860	0.0095
113	13.4965	13.4860	0.0105	66	13.4955	13.4860	0.0095
112	13.4965	13.4860	0.0105	64	13.4955	13.4860	0.0095
111	13.4965	13.4860	0.0105	62	13.4955	13.4860	0.0095
110	13.4965	13.4860	0.0105	60	13.4955	13.4860	0.0095
109	13.4965	13.4860	0.0105	58	13.4955	13.4860	0.0095
108	13.4965	13.4860	0.0105	56	13.4955	12.4860	0.0095
107	13.4965	13.4860	0.0105	54	13.4955	13.4860	0.0095
106	13.4965	13.4860	0.0105	52	13.4955	13.4860	0.0095
105	13.4965	13.4860	0.0105	50	13.4955	13.4860	0,0095
104	13.4965	13.4860	0.0105	48	13.4955	13.4860	0.0095
103	13.4965	13.4860	0.0105	46	13.4955	13.4860	0.0095
102	13.4965	13.4860	0.0105	44	13.4955	13.4860	0.0095
101	13.4965	13.4860	0.0105	42	13.4955	13.4860	0.0095
100	13.4965	13.4860	0.0105	40	13.4955	13.4860	0.0095
99	13.4965	13.4860	0.0105	38	13.4955	13.4860	0.0095
98	13.4965	13.4860	0.0105	36	13.4955	13.4860	0.0095
97	13.4965	13.4860	0.0105	34	13.4955	13.4860	0.0095
96	13.4965	13 4860	0.0105	32	13.4955	13.4860	0.0095
95	13.4965	13.4860	0.0105	30	13.4955	13.4860	0.0093
94	13.4965	13.4860	0.0105	28	13.4955	13.4860	9.0095
93	13.4965	13.4860	0.0105	26	13.4955	13.4860	0.0095
92	13.4965	13.4860	0.0105	24	13.4955	13.4860	0.0095
91	12.4965	13.4860	0.0105	22	13.4955	13.4860	0.0095
90	13.4965	13.4860	0.0105	20	13.4955	13.4860	0.0095
89	13.4965	13.4860	0.0105	18	13.4955	13.4860	0.0095
88	13.4965	13.4860	0.0105	16	13.4955	13.4860	0.0095
87	13.4965	13.4860	0.0105	14	13.4955	13.4860	0.0095
86	13.4965	13.4860	0.0105	12	13.4955	13.4860	0.0095
85	13.4965	13.4860	0.0105	10	13.4955	13.4860	0.0095
84	13.4965	13.4860	0.0105	8	13.4955	13.4860	0.0095
83	13.4965	13.4860	0.0105	6	13.4955	13.4860	0.0095
82	13.4965	13.4860	0.0105	4	13.4955	13.4860	0.0095
81	13.4965	13.4860	0.0105	2	13.4955	13.4860	0.0095
80	13.4965	13.4860	0.0105	1	13.4955	13.4860	0.0095
78	13.4965	13.4860	0.0105				

TABLE No. 2.—SPECIMEN No. 1, ENGLISH (RIDSDALE) BAR-IRON.

Table showing the extension, restoration, and permanent set caused by the under-mentioned weights per square inch of section, acting gradually upon a solid cylinder 1.996 *inches long between shoulders,* 0.582″ *in diameter, taken from a sample of English (Ridsdale) bar-iron (*3¼″ *by* 2″⅜ *to* 2″ *in cross-section,) along the fiber of the iron, used in the manufacture of coiled wrought-iron tubes for converting* 10-*inch smooth-bores into* 8-*inch rifles.*

Weight per square inch of section.	Extension per inch in length.	First difference.	Restoration per inch in length.	First difference.	Permanent set per inch in length.	First difference.
Pounds.						
1,879	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3,758	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5,638	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7,517	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9,397	0.0005	0.0005	0.0005	0.0005	0.0000	0.0000
11,276	0.0010	0.0005	0.0010	0.0005	0.0000	0.0000
13,155	0.0010	0.0000	0.0010	0.0000	0.0000	0.0000
15,035	0.0012	0.0002	0.0012	0.0002	0.0000	0.0000
16,914	0.0012	0.0000	0.0012	0.0000	0.0000	0.0000
18,794	0.0015	0.0003	0.0015	0.0003	0.0000	0.0000
20,673	0.0015	0.0000	0.0015	0.0000	0.0000	0.0000
22,552	0.0015	0.0000	0.0015	0.0000	0.0000	0.0000
24,432	0.0017	0.0002	0.0017	0.0002	0.0000	0.0000
26,563	0.0020	0.0003	0.0015	—0.0002	0.0005	0.0005
28,461	0.0030	0.0010	0.0015	0.0000	0.0015	0.0010
30,070	0.0075	0.0045	0.0020	0.0005	0.0055	0.0040
31,949	0.0135	0.0060	0.0015	—0.0005	0.0120	0.0065
33,829	0.0175	0.0040	0.0025	0.0010	0.0150	0.0030
35,708	0.0215	0.0040	0.0015	—0.0010	0.0200	0.0050
37,588	0.0290	0.0075	0.0025	0.0010	0.0265	0.0065
39,467	0.0405	0.0015	0.0025	0.0000	0.0380	0.0115
41,346	0.0445	0.0040	0.0025	0.0000	0.0420	0.0040
43,226	0.0546	0.0101	0.0030	0.0005	0.0516	0.0096
45,105	0.0666	0.0120	0.0020	—0.0010	0.0646	0.0130
46,985	0.0781	0.0115	0.0020	0.0000	0.0761	0.0115
48,864	0.1062	0.0281	0.0030	0.0010	0.1032	0.0271
50,743	0.1462	0.0400	0.0040	0.0010	0.1422	0.0390
51,122	0.2079	0.0617	0.0030	—0.0010	0.2049	0.0660
51,498	0.2114	0.0035	0.0035	0.0005	0.2079	0.0030
51,874	0.2179	0.0065	0.0040	0.0005	0.2135	0.0056
52,250	0.2329	0.0150	0.0005	—0.0005	0.2324	0.0189
52,437	0.3015	Specimen broke.				

Specimen No. 1.

Specific gravity	7.6949	Tensile strength, pounds	52,437
Original diameter	0″.582	Elastic limit, pounds	25,000
Diameter at point of rupture	0″.425	Total elongation per inch	0″.3015
Character of rupture	Fibrous.	Position of rupture	Middle.
Hardness	8.3941		

Plate II.

8 INCH RIFLE No. 2. converted, steel tube.

Fig. 2.

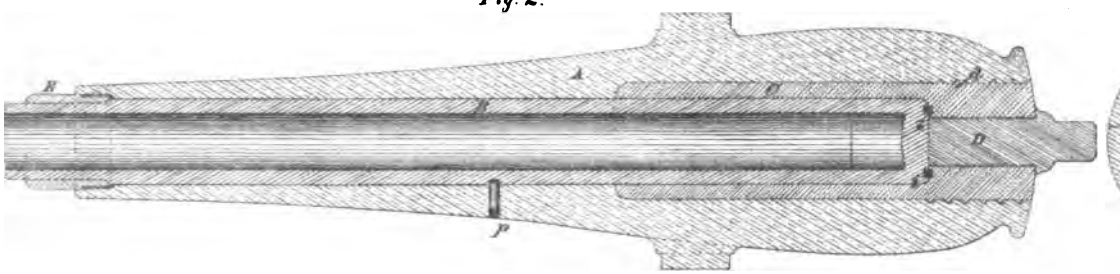
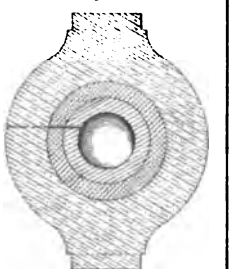


Fig. 4.



Section on ef.

Fig. 1.

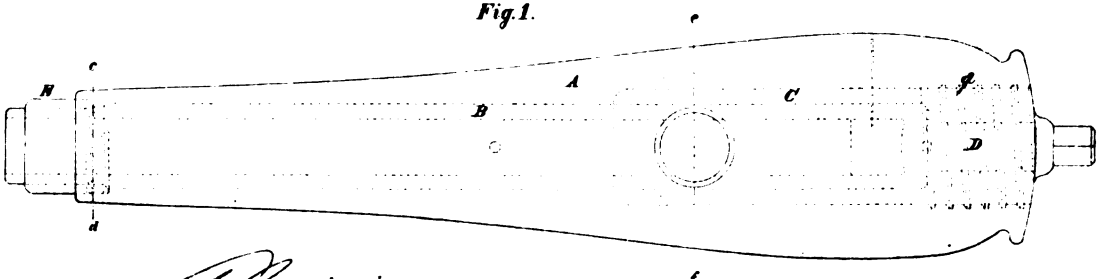


Fig. 3.

Section on cd.

Steel

S. Crispin
Bot Col & Sa Lt Col of Ord
Constructor of Ord.

Cast iron.

TABLE No. 3.—SPECIMEN No. 2, ENGLISH (RIDSDALE) BAR-IRON.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of section acting gradually upon a solid cylinder 1.996 inches long between shoulders, and 0".582 in diameter, taken from as ample of English (Ridsdale) bar-iron, (3¼" by 2" ⅝ to 2" in cross-section,) along the fiber of the iron used in the manufacture of coiled wrought-iron tubes for converting 10-inch smooth-bores into 8-inch rifles.

Weight per square inch of section.	Extension per inch in length.	First difference.	Restoration per inch in length.	First difference.	Permanent set per inch in length.	First difference.
Pounds.						
1,877	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3,754	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5,637	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7,509	0.0005	0.0005	0.0005	0.0005	0.0000	0.0000
9,386	0.0005	0.0000	0.0005	0.0000	0.0000	0.0000
11,263	0.0010	0.0005	0.0010	0.0005	0.0000	0.0000
13,141	0.0010	0.0000	0.0010	0.0000	0.0000	0.0000
15,018	0.0010	0.0000	0.0010	0.0000	0.0000	0.0000
16,895	0.0010	0.0000	0.0010	0.0000	0.0000	0.0000
18,773	0.0015	0.0005	0.0015	0.0005	0.0000	0.0000
20,650	0.0015	0.0000	0.0015	0.0000	0.0000	0.0000
22,527	0.0015	0.0000	0.0015	−0.0000	0.0000	0.0000
24,404	0.0020	0.0005	0.0015	0.0000	0.0005	0.0005
26,282	0.0020	0.0000	0.0010	−0.0005	0.0010	0.0005
28,159	0.0020	0.0000	0.0010	0.0000	0.0010	0.0000
30,036	0.0025	0.0005	0.0015	0.0005	0.0015	0.0005
31,914	0.0090	0.0065	0.0015	0.0000	0.0075	0.0060
33,791	0.0130	0.0040	0.0010	−0.0005	0.0120	0.0045
35,668	0.0170	0.0040	0.0015	0.0005	0.0155	0.0035
37,546	0.0205	0.0035	0.0015	0.0000	0.0190	0.0035
39,423	0.0255	0.0050	0.0015	0.0000	0.0240	0.0050
41,300	0.0410	0.0155	0.0010	−0.0005	0.0300	0.0060
43,177	0.0485	0.0075	0.0020	0.0010	0.0465	0.0165
45,055	0.0595	0.0110	0.0020	0.0000	0.0575	0.0110
46,932	0.0715	0.0120	0.0020	0.0000	0.0700	0.0125
48,809	0.0875	0.0160	0.0015	−0.0005	0.0860	0.0160
50,687	0.1135	0.0260	0.0025	0.0000	0.1110	0.0250
52,564	0.2220	0.1085	0.0015	−0.0010	0.2205	0.0195
52,632	0.2965	0.0745	Specimen broken.			

Specimen No. 2.

Specific gravity	7.6861	Tensile strength, pounds	52,632
Original diameter	0".582	Elastic limit, pounds	24,000
Diameter at point of rupture	0".433	Total elongation per inch	0".2965
Character of rupture	Fibrous.	Position of rupture	Middle.
Hardness	8.9297		

EIGHT-INCH RIFLE No. 2, CONVERTED—STEEL-LINED.

Description of the gun.

Plate II, Fig. 2, A, is the ten-inch Rodman gun, bored up to the sufficient interior diameters for the reception of the steel tube B, with its jacket C. The prescribed thickness of the tube is 2 inches, and of the

jacket 2 inches, so that the diameter of the larger part of the bore of the casing should be 16 inches, and of the smaller part 12 inches. The tube is inserted through the breech, and by mechanical means; it is secured in position by the heavy thread *a*, upon the base of the jacket, by the screw-collar E, at the muzzle, and by the pin *p*, tapped through the side of the casing and into the tube. The jacket is shrunk upon the tube, and extends, from a point a short distance in front of the trunnions of the gun, throughout the remaining lower portion of the tube, and beyond it to the face of the breech. It thus overlaps the tube by about 19″.25, and though of greater thickness in this part than where it embraces the tube, yet it is made hollow, in order that the entire jacket may have the ability to expand in unison with the tube, when the latter is distended under the strain of discharge. A thread is cut upon the interior of this portion of the jacket for the reception of the breech-plug D. The tube extends beyond the bore of the casing some 10 inches, and is strengthened by the muzzle-collar, which also projects beyond the casing. The thread upon the base of the jacket is square cut, and is of such area of cross-section as to have its strength proportional to the strength of the female thread in the cast iron. By these arrangements the greatest resistance is secured to a longitudinal thrust. The jacket is prevented from turning upon the tube during the operation of screwing the two into the threads prepared for them in the casing, by the dowels *i*, *i*. These dowels are screwed into the bottom of the tube, but enter simply a recess in the shoulder of the jacket.

RIFLING, VENTING, ETC.

The rifling and venting of this gun are the same as in the 8-inch converted gun No. 1, wrought-iron tubing.

FABRICATION OF THE GUN.

The work of conversion was performed at the West Point foundry. The 10-inch Rodman smooth-bore gun selected for the conversion was manufactured at the South Boston foundry, and was inspected and proved in 1866. The mechanical tests of the metal employed gave the following results:

Density	7.2767
Tenacity, pounds per square inch	32.674
Initial tension, pounds	10.000

The steel tube and jacket used in the conversion were manufactured by the Bochum Manufacturing Company, Bochum, Prussia, and were tested with the following results.

Specimen.	Density.	Area of section broken.	Tenacity per square inch.
		Inches.	*Pounds.*
Steel tube No. 1	7.8807	0.2863	99,196
Steel tube No. 2	7.9083	0.2863	76,843
Steel jacket No. 1	7.8542	0.2865	88,291
Steel jacket No. 2	7.8733	0.2856	91,992

The specimens were taken from opposite sides of the muzzle-end of the tube, and from opposite sides of the solid (breech) end of the jacket.

It will be observed that the steel tube was much more dense, and at the same time weaker, upon one side than upon the other.

The cast-iron body was first bored up to a mean diameter of 16 .010 and for a distance of 54".75 from the breech, at which point it was rounded down to a diameter of 12 inches, and this diameter continued through to the muzzle. The interior of the steel jacket was next bored to a diameter ranging from 12".005 to 12".035, and that portion of the steel tube intended to be embraced by the jacket was turned to a diameter of 12".014. The jacket was then shrunk upon the tube. The exteriors of the tube and jacket were then turned to diameters as nearly approaching those of the larger and smaller portions of the cast iron body as was compatible with their insertion by mechanical means, and a screw-thread was cut upon the base of the jacket to correspond to that cut in the breech of the casing.

The tube and jacket, as a whole, were then inserted, forced down in the casing, and screwed home into position by means of levers, after which the muzzle-collar was screwed in and the steel pins inserted.

Table 1 shows the relative diameters of the tube and jacket and the bore of the casing.

Table 2 shows the relative diameters of the tube and the interior of the jacket.

INSPECTION.

The finished gun was duly inspected, and showed good workmanship.

PRINCIPAL DIMENSIONS.

Length of bore	127.78	inches.
Length of tube	131.65	inches.
Length of jacket	60.	inches.
Exterior diameters of steel jacket	15.980	inches.
	16.085	inches.
Interior diameters of steel jacket	12.005	inches.
	12.035	inches.
Exterior diameter of tube	11.993	inches.
Interior diameter of tube	8.	inches.
Thickness of walls of jacket	1.994	inches.
Thickness of walls of tube	1.996	inches.
Thickness of bottom of tube	3.85	inches.
Thickness through breech	19.35	inches.
Diameter of breech-plug through threads	7.	inches.
Number of lands and grooves	15.	
Width of lands and grooves	0.8377	inch.
Depth of grooves (prescribed 0".075)	0.060	inch.
Pitch, uniform, one turn in 40 feet.		
Weight of gun	16,500	pounds.
Counter-preponderance at face of breech	920	pounds.

NOTE.—The general record of gun No. 2 is as follows:

(*Extract from report of Board on gun No. 2.*)

Six preliminary rounds were fired, using charges ranging from 20 to 30 pounds, as in gun No. 1. Four hundred and fifty rounds were fired with battering charges of 35 pounds of hexagonal powder, and an average weight of projectile (Butler) of 172½ pounds.

All examinations up to the 170th fire failed to discover any evidence of injury to the system; but impressions taken of the bore at this round showed a fine line extending from the commencement of the land immediately in front of the vent to the copper

bushing. This proved to be an initial rupture, as at 175 rounds a crack had developed from the vent to the muzzle, in and through the tube. The firings were continued from this point up to the 456th (the breaking round) making a total of 286 rounds which the system endured after the rupture of the tube.

The full details of the trial of this gun will be submitted in the report of the Ordnance Board.

Specimens taken from a fragment of the breech-end of the tube were tested with the following results:

Specimens.	Density.	Tenacity per square inch.	Area of section.	
			Before rupture.	After rupture.
Longitudinal, rear chamber	7.8548	*56,222	0.35573	0.26057
Tangential, rear chamber	7.8481	81,522	0.35573	0.25607
Longitudinal, 3 feet from bottom	7.8548	78,898	0.35361	0.26148
Tangential, 3 feet from bottom	7.8514	78,430	0.35573	0.27525

* Doubtful. Specimens 1 and 2 showed a finer grain on rupture than 3 and 4.

TABLE No. 1.—EIGHT-INCH EXPERIMENTAL RIFLE No. 2.

Table showing exterior diameter of tube and interior of jacket.

Inches from breech.	Exterior diameter of tube.	Interior diameter of jacket.	Difference or shrinkage.	Inches from breech.	Exterior diameter of tube.	Interior diameter of jacket.	Difference or shrinkage.
45	12.014	12.0035	0.0105	21	12.014	12.0035	0.0105
44	12.014	12.004	0.010	20	12.014	12.0035	0.0105
43	12.014	12.004	0.010	19	12.014	12.004	0.010
42	12.014	12.0035	0.0105	18	12.014	12.004	0.010
41	12.014	12.0035	0.0105	17	12.014	12.004	0.010
40	12.014	12.0035	0.0105	16	12.014	12.004	0.010
39	12.014	12.0035	0.0105	15	12.014	12.004	0.010
38	12.014	12.0035	0.0105	14	12.014	12.004	0.010
37	12.014	12.0035	0.0105	13	12.014	12.004	0.010
36	12.014	12.0035	0.0105	12	12.014	12.004	0.010
35	12.014	12.004	0.010	11	12.014	12.004	0.010
34	12.014	12.004	0.010	10	12.014	12.004	0.010
33	12.014	12.004	0.010	9	12.014	12.004	0.010
32	12.014	12.004	0.010	8	12.014	12.005	0.009
31	12.014	12.0035	0.0105	7	12.014	12.005	0.009
30	12.014	12.0035	0.0105	6	12.014	12.005	0.009
29	12.014	12.0035	0.0105	5	12.014	12.005	0.009
28	12.014	12.0035	0.0105	4	12.014	12.005	0.009
27	12.014	12.0035	0.0105	3	12.014	12.005	0.009
26	12.014	12.0035	0.0105	2	12.014	12.005	0.009
25	12.014	12.0035	0.0105	1	12.014	12.005	0.009
24	12.014	12.0035	0.0105				
23	12.014	12.0035	0.0105				
22	12.014	12.0035	0.0105				

TABLE NO. 2.—EIGHT-INCH EXPERIMENTAL RIFLE NO. 2.

Table showing interior diameter of cast-iron body and exterior diameter of steel tube and jacket prepared for insertion therein.

Inches from muzzle.	Interior diameter of casing.	Exterior diameter of tube.	Difference or play of tube.	Inches from breech.	Interior diameter of casing.	Exterior diameter of jacket.	Difference or play of jacket.
82	12.000	11.993	0.007	56	15.985	15.980	0.005
81	12.000	11.993	.007	55	16.011	16.060	.005
80	12.000	11.993	.007	54	16.012	16.007	.005
78	12.000	11.993	.007	53	16.012	16.007	.005
76	12.000	11.993	.007	52	16.012	16.007	.005
74	12.000	11.993	.007	50	16.012	16.007	.005
72	12.000	11.993	.007	48	16.012	16.007	.005
70	12.000	11.993	.007	46	16.012	16.007	.005
68	12.000	11.993	.007	44	16.012	16.007	.005
66	12.000	11.993	.007	42	16.012	16.007	.005
64	12.000	11.993	.007	40	16.012	16.007	.005
62	12.000	11.993	.007	38	16.012	16.007	.005
60	12.000	11.993	.007	36	16.012	16.007	.005
58	12.000	11.993	.007	34	16.012	16.007	.005
56	12.000	11.993	.007	32	16.012	16.007	.005
54	12.000	11.993	.007	30	16.012	16.007	.005
52	12.000	11.993	.007	29	16.013	16.008	.005
50	12.000	11.993	.007	28	16.012	16.008	.005
48	12.000	11.993	.007	27	16.012	16.008	.005
46	12.000	11.993	.007	26	16.012	16.008	.005
44	12.000	11.993	.007	25	16.012	16.008	.005
42	12.000	11.993	.007	24	16.014	16.009	.005
40	12.000	11.993	.007	23	16.014	16.009	.005
38	12.000	11.993	.007	22	16.014	16.009	.005
36	12.000	11.993	.007	21	16.014	16.009	.005
34	12.000	11.993	.007	20	16.015	16.010	.005
32	12.000	11.993	.007	19	16.016	16.011	.005
30	12.000	11.993	.007	18	16.016	16.011	.005
28	12.000	11.993	.007	17	16.017	16.012	.005
26	12.000	11.993	.007	16	16.018	16.013	.005
24	12.000	11.993	.007	15	16.018	16.018	.005
22	12.000	11.993	.007	14	16.020	16.015	.005
20	12.000	11.993	.007	13	16.021	16.016	.005
18	12.000	11.993	.007	12	16.023	16.018	.005
16	12.000	11.993	.007	11	16.026	16.021	.005
14	12.000	11.993	.007	10	16.030	16.025	.005
12	12.000	11.993	.007	9	16.035	16.025	.010
10	12.000	11.993	.007	8	16.035	16.025	.010
8	12.000	11.993	.007	7	16.035	16.025	.010
6	12.000	11.993	.007	6	16.035	16.025	.010
4	12.000	11.993	.007	5	16.035	16.025	.010
2	12.000	11.993	.007	4	16.035	16.025	.010
1	12.000	11.933	.007	3	16.035	16.025	.010
				2	16.035	16.025	.010
				1	16.035	16.025	.010

NINE-INCH RIFLE No. 3, CONVERTED—WROUGHT-IRON LINED.*

Description of the gun.

PLATE III. This gun conforms in all respects, except in caliber, rifling and thickness of tube, to the 8-inch wrought-iron-lined gun No. The exterior diameter of the tube is the same, but as the caliber is one inch greater, the thickness of the wall of the tube is only 2″.25 thick instead of 2″.75, as in the 8-inch gun.

RIFLING AND VENTING.

The gun is rifled with seventeen lands and grooves each, of equal width. Width of grooves and lands, 0″.8316. Depth of grooves, 0″.08. Twist uniform, one turn in 45 feet.

The rifling stops at a point 11 inches from the bottom of the bore.

The gun is vented in the same manner as the 8-inch converted gun No. 1.

FABRICATION.

The gun was converted at the West Point foundry. The cast-iron body was manufactured at the South Boston foundry, and inspected and proved in 1866. The metal of the gun had been tested, with the following results: Density, 7.2636; tenacity, 32,538 pounds; initial tension, 10,000 pounds.

The tube was manufactured at Sir William Armstrong's works, at New Castle-upon-Tyne, England, and was bored to the true interior diameter but left with an excess of metal upon the exterior, in order that it might be turned to fit the casing. The quality of the metal purported to be about the same as that of the metal in the 8-inch wrought-iron tube used in gun No. 1.

The various operations of boring up the casing, turning and rifling the tube, and inserting the latter into the casing, were in every way similar to those pursued in the conversion of the 8-inch gun No. 1, wrought-iron lined.

Table 1 shows the relative diameters of the tube and casing.

INSPECTION.

The gun was duly inspected, and showed evidence of good workmanship and finish.

Principal dimensions.

Length of bore	117.25	inches
Length of tube	120.	"
Length of jacket	32.75	"
Exterior diameter of tube	14.855	"
Diameter of tube under jacket	10.003	"
Interior diameter of jacket	10.	"
Length of rifled portion of bore	107.25	"
Thickness of wrought-iron cup at bottom of tube	2.75	"

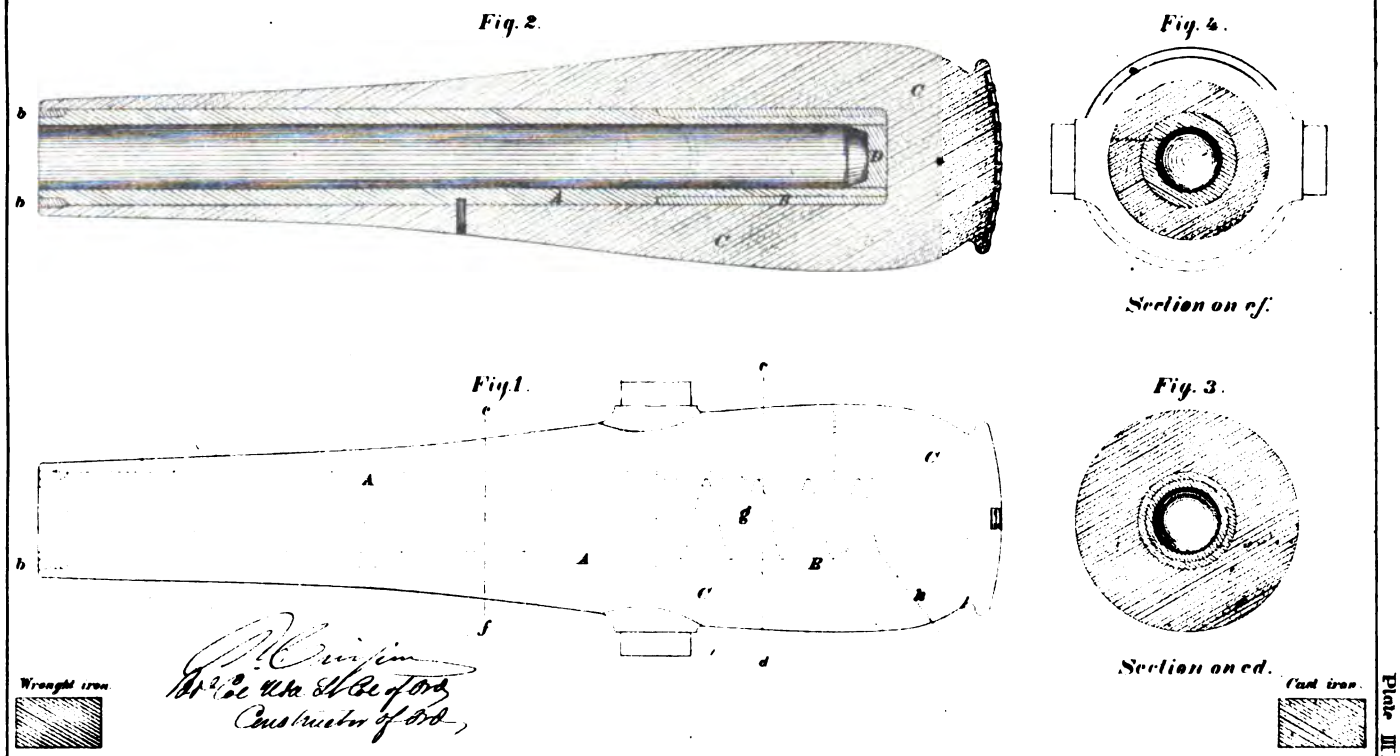
* *Experiments and tests*—The gun has been fired at Sandy Hook, under the direction of the ordnance board, 502 rounds, full details of which are embodied in the report submitted by the board to the Chief of Ordnance, June 28, 1876; details are therefore omitted here.

The projectiles employed are shown on Plate V.

Carriage.—The carriage provided for this gun during the tests is fully described in the detailed report of the ordnance board, dated June 28, 1876, upon the trial of this gun. It is shown on Plate VI, and has attached the rack and pinion device for elevating and depressing the gun, and a hydraulic buffer to check the recoil.

Plate III.

9 INCH RIFLE No. 3. converted, wrought iron tube.



Number of grooves and lands ..... 77.
Width of grooves and lands ..... 0.8818 inch.
Depth of grooves ..... 0.06 "
Twist uniform one turn in 45 feet.
Weight of gun ..... 15 000 pounds
Counter-recoil force ..... 450 pounds

TABLE No. 1.—NINE-INCH CONVERTED RIFLE No. 3.

Relative diameters of bore of nine-inch body of 10-inch gun and mean tube for one-inch therein, at different points of bore of indicated length.

Inches from face of muzzle.	Interior diameter of bore.	Exterior diameter of tube.	Difference.	Inches from face of muzzle.	Interior diameter of bore.	Exterior diameter of tube.	Difference.
118	13.4965	13.4855	0.0110	78	13.4960	13.4850	0.0110
117	13.4965	13.4855	0.0110	76	13.4960	13.4850	0.0110
116	13.4965	13.4855	0.0110	74	13.4960	13.4850	0.0105
115	13.4965	13.4855	0.0110	72	13.4960	13.4850	0.0105
114	13.4965	13.4855	0.0110	70	13.4960	13.4850	0.0105
113	13.4965	13.4855	0.0110	68	13.4960	13.4850	0.0105
112	13.4965	13.4855	0.0110	66	13.4960	13.4850	0.0105
111	13.4965	13.4855	0.0110	64	13.4960	13.4850	0.0105
110	13.4965	13.4855	0.0110	62	13.4960	13.4850	0.0105
109	13.4965	13.4855	0.0110	60	13.4960	13.4850	0.0105
108	13.4965	13.4855	0.0110	58	13.4960	13.4850	0.0105
107	13.4965	13.4855	0.0110	56	13.4960	13.4850	0.0105
106	13.4965	13.4855	0.0110	54	13.4960	13.4850	0.0105
105	13.4965	13.4855	0.0110	52	13.4960	13.4850	0.0105
104	13.4965	13.4855	0.0110	50	13.4960	13.4850	0.0105
103	13.4965	13.4855	0.0110	48	13.4960	13.4850	0.0105
102	13.4965	13.4855	0.0110	46	13.4960	13.4850	0.0105
101	13.4965	13.4855	0.0110	44	13.4960	13.4850	0.0105
100	13.4965	13.4855	0.0110	42	13.4960	13.4850	0.0105
99	13.4965	13.4855	0.0110	40	13.4960	13.4850	0.0105
98	13.4965	13.4855	0.0110	38	13.4960	13.4850	0.0105
97	13.4965	13.4855	0.0110	36	13.4960	13.4850	0.0105
96	13.4965	13.4855	0.0110	34	13.4960	13.4850	0.0105
95	13.4965	13.4855	0.0110	32	13.4960	13.4850	0.0105
94	13.4965	13.4855	0.0110	30	13.4960	13.4850	0.0105
93	13.4965	13.4855	0.0110	28	13.4960	13.4850	0.0105
92	13.4965	13.4855	0.0110	26	13.4960	13.4850	0.0105
91	13.4965	13.4855	0.0110	24	13.4960	13.4850	0.0105
90	13.4965	13.4855	0.0110	22	13.4960	13.4850	0.0105
89	13.4965	13.4855	0.0110	20	13.4960	13.4850	0.0105
88	13.4965	13.4855	0.0110	18	13.4960	13.4850	0.0105
87	13.4965	13.4855	0.0110	16	13.4960	13.4850	0.0105
86	13.4965	13.4855	0.0110	14	13.4960	13.4850	0.0105
85	13.4965	13.4855	0.0110	12	13.4960	13.4850	0.0105
84	13.4965	13.4855	0.0110	10	13.4960	13.4850	0.0105
83	13.4965	13.4855	0.0110	8	13.4960	13.4850	0.0105
82	13.4965	13.4855	0.0110	6	13.4960	13.4850	0.0105
81	13.4965	13.4855	0.0110	4	13.4960	13.4850	0.0105
80	13.4965	13.4855	0.0110	2	13.4960	13.4850	0.0105

NINE-INCH RIFLE No. 4, CONVERTED—STEEL-LINED.*

Description of the gun.

The description of this gun is identical in every respect with that of the 8-inch converted gun No. 2, steel-lined, except that, as the tube was inserted by the application of heat to the cast-iron casing, due allowance for shrinkage was made in the relative diameters of the tube and casing; and, further, as the caliber of this gun was 9 inch instead of 8 inch, the diameter of the larger part of the bore of the casing was 17″.35 and of the smaller part 13″.2, the thickness of the tube being 2″.1 and of the jacket 2″.075. (See Plate IV.)

The rifling and venting of this gun are the same as in the 9-inch converted gun No. 3, with wrought-iron tubing.

FABRICATION.

The gun selected for this conversion was a new 10-inch Rodman gun, manufactured at the South Boston foundry in 1866.

The details for the conversion of this gun into a steel-lined rifle contemplated, first, the shrinking of the steel jacket over the breech-end of the steel tube, and then the insertion of the jacketed tube into the cast-iron gun, with the allowance for shrinkage deemed necessary to secure not merely a perfect contact between the cast iron and steel, but to subject the former to a slight tension. The interior diameters of the gun were accordingly made smaller than the bodies over which the gun was to be shrunk. (See table 2.)

The interior of the steel jacket was bored to a diameter of from 13″.215 to 13″.217, measuring very uniformly throughout. The breech-end of the tube, for a distance of 45 inches, was then turned to a diameter of 13″.220 to 13″.221. This diameter of the tube, therefore, exceeded the interior diameter of the jacket from 0.003 to 0.006, thus leaving a surplus of metal upon the former of from 0.0015 to 0.003. (See table 1.)

The shrinking of the jacket upon the tube having been effected, the jacketed tube was turned to the dimensions shown in table No. 2.

As the cast-iron body of the gun had to be heated up for the reception of the interior steel lining, the following arrangements were made for conducting the operation: A pit was made, in convenient proximity to a lifting crane, of a depth sufficient to receive the entire gun. Four small furnaces or grate-fires were erected in it. A circular foundation-wall of brick masonry, 12 inches thick and 3 feet high, was first built; then the four furnaces. This wall, the top of which was on a level with the tops of the furnaces, supported a number of large cast-iron circular drums, flanged, and connected by bolts. The interior of the drums was thickly lined with fire-clay. A passage-way was constructed, which allowed access to the furnaces, the doors of the furnaces opening into the passage. Flues for the furnaces led up the sides of the pit, and were extended above it by means of wrought-iron pipes 12 inches in diameter, and provided with dampers The pit was covered with wrought-iron plates having a number of valves or ventilators for the

**Experiments and tests.*—This gun has been fired at Sandy Hook, up to date, 117 rounds, under the direction of the ordnance board, and is so far in a sound and serviceable condition.

Carriage.—The gun is mounted on a carriage similar to that provided for the 8-inch converted gun No. 1, and described in the report of the ordnance board on the trial of that gun. (See report of the Chief of Ordnance for 1875, page 97.)

Plate IV.

9 INCH RIFLE No. 4. converted. steel tube.

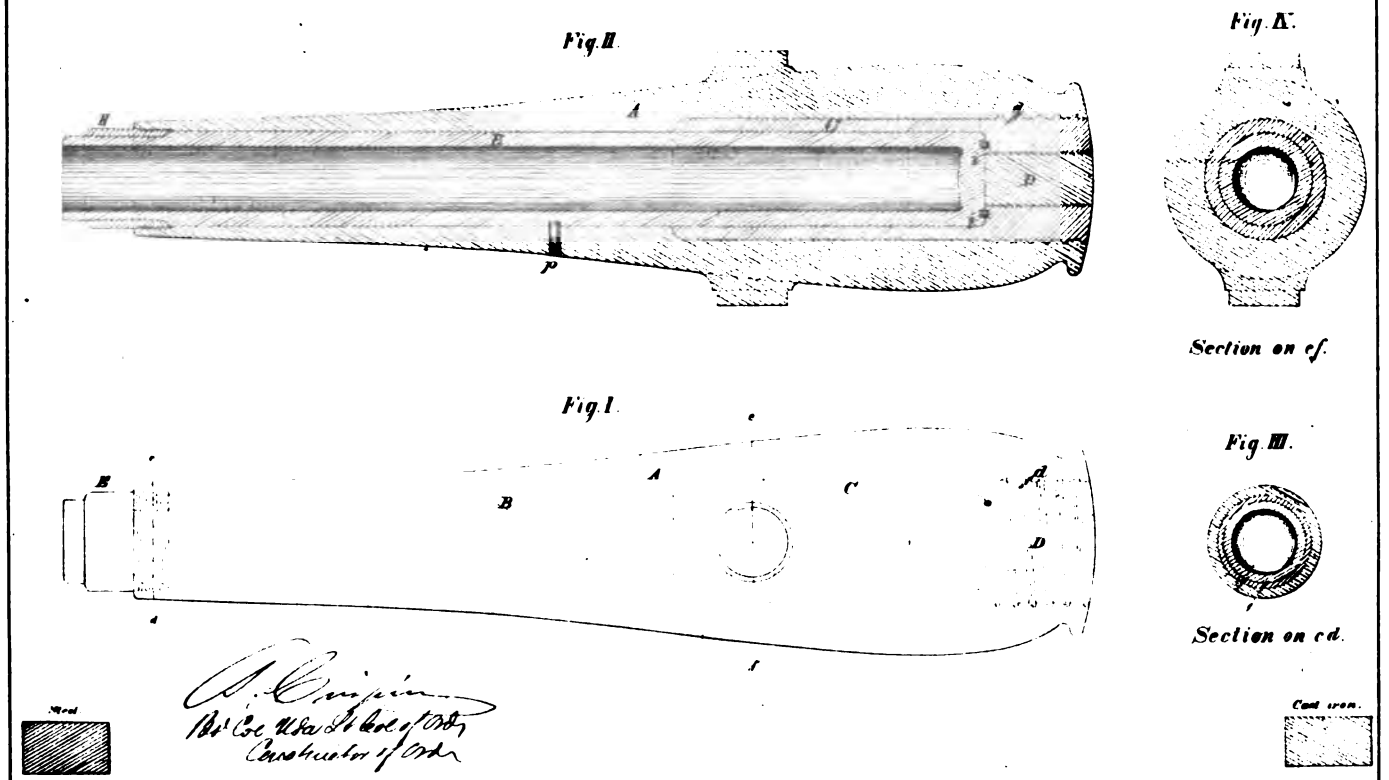
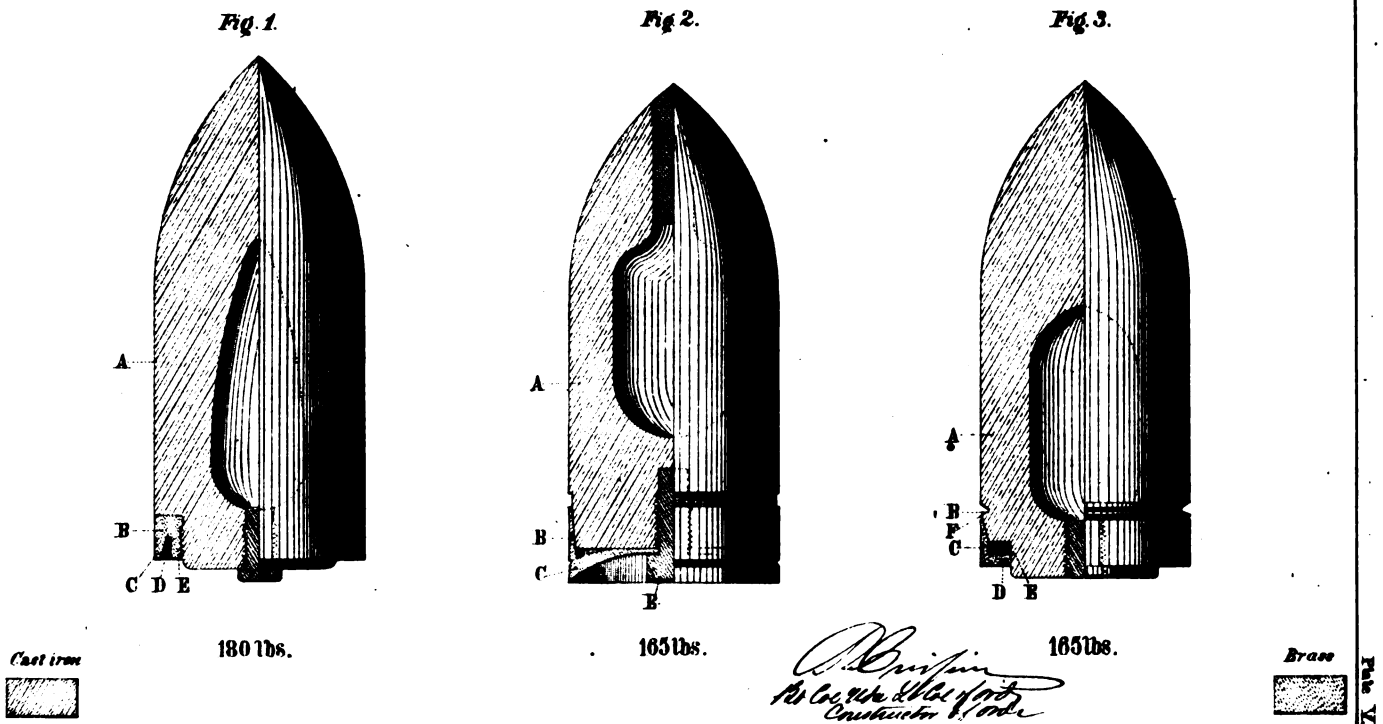


Plate V.

PROJECTILES FOR 8 & 9 INCH CONVERTED RIFLES.



10 INCH CARRIAGE WITH HYDRAULIC RECOIL CHECK.

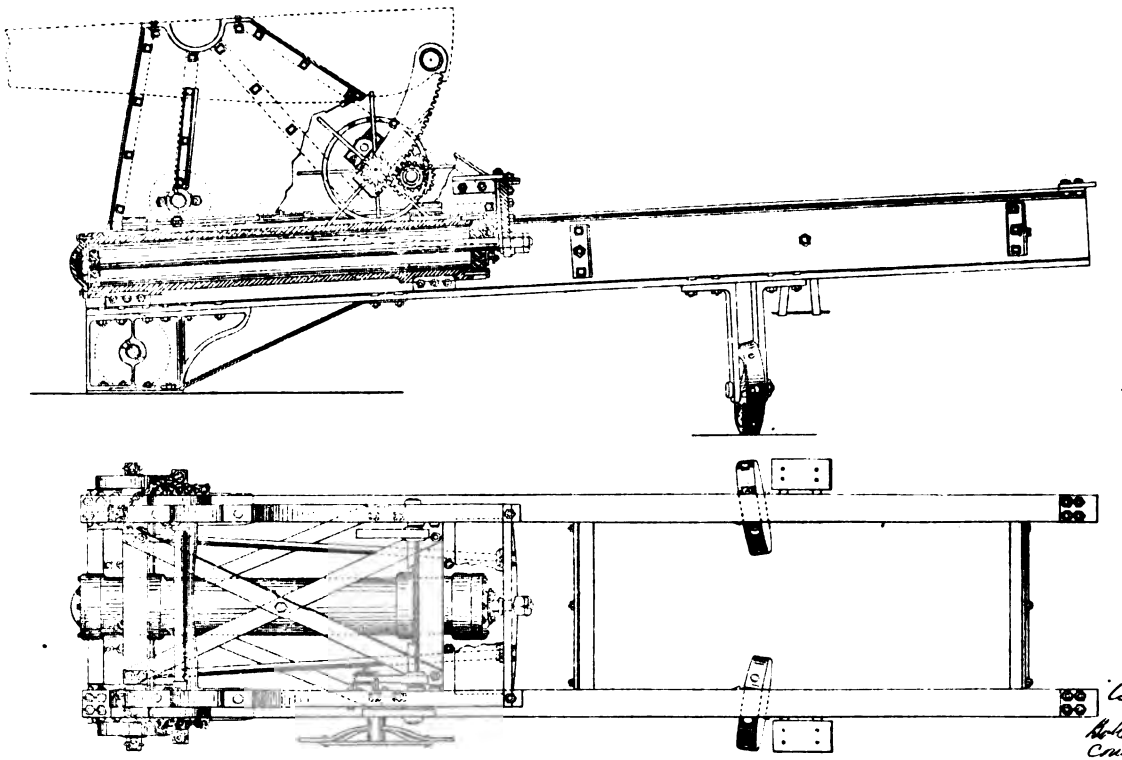


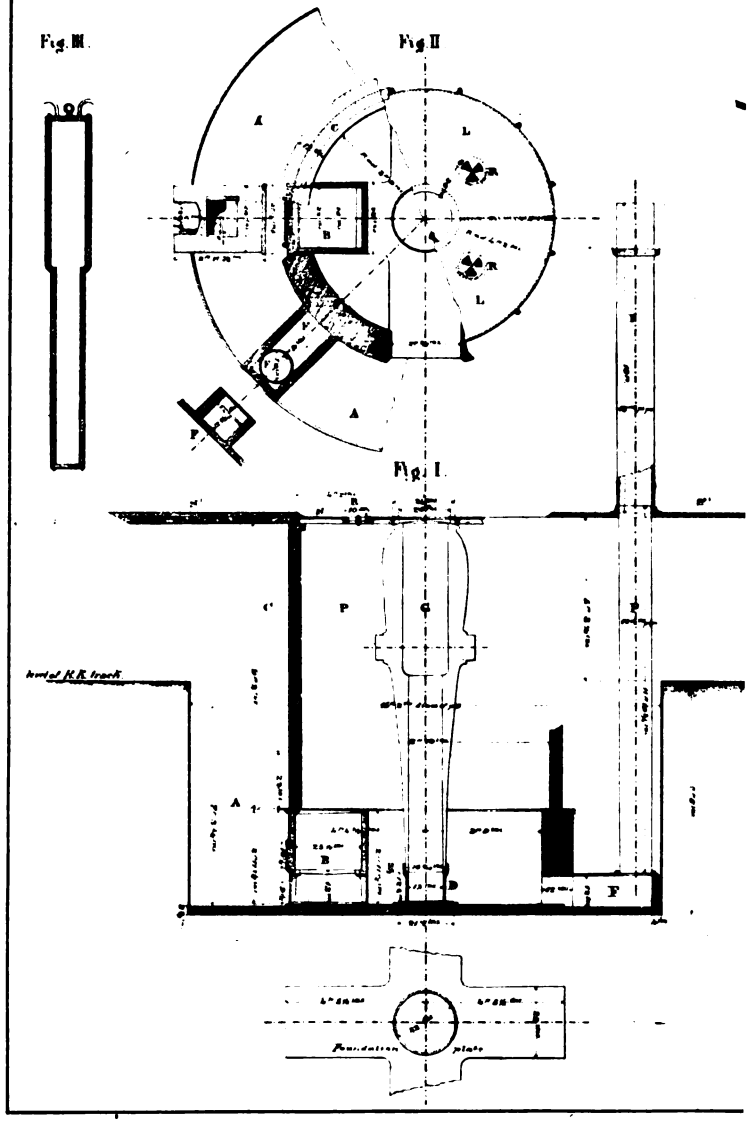
Plate XI

Arrangement for heating a 9 Inch Rodman gun prior to introducing a steel tube into the bore.

at

WEST POINT FOUNDRY.

Scale $\frac{1}{40}$.



ulation of the heat, as auxiliaries to the flue-dampers. A center-ce in the covering was provided, so that the breech of the gun could exposed when in position. The gun was placed vertically, breech in the pit, the muzzle resting upon the rim of a cast-iron cylinder ced upon a firm foundation. The interior of this cylinder was adapted the reception of the muzzle-end of the steel tube, which, when ome," extends beyond the muzzle of the cast-iron casing. The gun s securely braced in this position, the breech being almost flush with e pit-covering.

Referring to the Plate, the arrangements will be found illustrated follows: P, the interior of the pit; G, the cast iron body of the gun position, and resting on the cast-iron cylinder D. One of the fur ces is shown at B. C C are the circular cast-iron drums; F is one of e flues; S is the sheet-iron covering; R, the ventilators; S′, a plank ging for the workmen; and A, the circular passage-way around the .

To guard against the possibility of warping in the gun-casing, or of insufficient expansion, unsuitable to the ready insertion of the lining, trial-tube was made of cast iron, (Fig. III,) accurately turned to the rresponding dimensions of the jacketed tube, to test the condition of e casing by insertion and withdrawal prior to the operation of inserting e tube proper.

The muzzle-end of the test tube was closed by a water-tight cap. A milar cap closed the breech-end, excepting that it was provided with wo short tubes to attach an inlet and outlet pipe for the passage of a urrent of water. In its center was secured a strong eye-bolt.

These arrangements were made so as to secure promptly the flow of a volume of water through the tube, to cool and contract it, provided it should stick on the trial in the attempt to withdraw it. Marks should be found, of course, if it stuck, which would indicate the part to be straightened in the casing, which of course could be secured by the proper application of heat. For the purpose of handling the tube the breech-plug was removed, and into its cavity was screwed a cast-iron tompion having a swivel-loop in its center from which to suspend it vertically in the crane, and sockets at its periphery for the reception of handspikes. (See Plate, Fig. IV.)

All being in readiness, the gun was fixed in position, the fires started, and the temperature of the pit kept at about 700°. At the expiration of twelve hours the larger part of the bore had expanded from 17″.347 to 17″.423 diameter, a difference of 0″.076; and this being nearly the full expansion due to the temperature applied, the straightness of the bore was first verified by means of the test-tube, after which the jacketed steel tube was swung vertically over the gun and lowered rapidly therein until the steel thread had entered the cast iron. Handspikes were then inserted in the sockets of the tompion, and the tube rapidly screwed home. The fires were then withdrawn and the gun allowed to cool.

When the gun had cooled it was removed from the pit, the breech-block replaced, the muzzle-collar and dowel-pin applied, and the finishing cut taken out of the bore, after which the bore was rifled, and the vent drilled and bushed.

Principal dimensions of 10-inch Rodman smooth-bore gun, No. 165, converted to 9-inch rifle No. 3.

Projection of tube and muzzle-collar beyond cast iron	7	inches.
Exterior diameter of muzzle-collar	13.50	"
Exterior diameter of tube	13.20	"
Exterior diameter of jacket	17.35	"
Thickness of tube	2.10	"
Thickness of jacket	2.075	"
Length of tube over all	131.16	"
Length of jacket over all	60.00	"
Thickness of bottom of tube	3.75	"
Thickness of breech	19.25	"
Depth of thread on jacket	0.40	inch.
Number of threads	5½	
Length of bore	127.41	inches.
Distance of vent from bottom of bore	3.5	"
Number of grooves and lands	17	
Width of grooves and lands	.8320	inch.
Depth of grooves	.065	"
Twist uniform, one turn in 60 calibers, or 45 feet.		
Total weight of gun	15,800	pounds.
Muzzle preponderance	250	"

The gun is 250 pounds heavy at the face of the muzzle, which makes a counter-preponderance at the face of the breech of about 500 pounds.

The mechanical tests of the materials in this gun will be found in Tables 4, 5, 6, and 7.

The results may be briefly summarized as follows:

10-inch smooth-bore gun. R. No. 165. F. No. 2260.

Average density of cast iron	7.2636	
Initial tension per square inch	10,800	pounds.
Tensile strength per square inch	32,538	"
Total weight of gun	15,130	"
Weight after conversion	15,800	"

STEEL TUBE.

The steel tube was manufactured by the Bochum Steel Company.

Physical properties.

Specimens.	Density.	Tenacity.	Extension per inch in length, at 60,000 pounds per square inch applied.	Restoration per inch in length for 60,000 pounds per square inch applied.	Permanent set per inch in length for 60,000 pounds per square inch applied.	Elastic limit.
		Pounds.				*Pounds.*
Specimen A, from breech-end	7.8598	88,386	.....	.....	.....	.....
Specimen B, from breech-end	7.8582	90,085	.....	.....	.....	.....
Specimen C, from side	7.8634	73,000	0.04300	0.00260	0.04040	25,600
Specimen D, from side	7.8634	72,000	0.04000	0.00240	0.03760	23,000
Specimen E, from side	7.8704	74,000	0.03900	0.00220	0.03680	25,600

STEEL JACKET.

Physical properties.

Specimens.	Density.	Tenacity.	Extension per inch in length, at 60,000 pounds per square inch applied.	Restoration per inch in length for 60,000 pounds per square inch applied.	Permanent set per inch in length for 60,000 pounds per square inch applied.	Elastic limit.
		Pounds.				*Pounds.*
Specimen F, from front	.....	.....	.....	.....	.....	.....
Specimen G, from front	.....	.....	.....	.....	.....	.....
Specimen H, from breech-end	7.8818	*64,000	0.08470	0.00270	0.08200	19,000

NOTE.—No more specimens could be taken from the jacket.
* Slight defect.

An examination of the tables shows that the steel of both tube and jacket is rather too high to give the best results, although it is reasonably uniform in quality. But for a minute defect, specimen H from the steel jacket would probably have reached a fair tensile resistance. It appears somewhat softer than the tube specimens, C, D, and E, but the latter were cut from the exterior of the tube, while specimen H was cut from the interior of the breech-end of the jacket.

A steel cylinder sent by the Bochum Mining and Cast-Steel Company, Prussia, a few years since, would seem to fulfill more perfectly the requirements of a good steel for gun-construction. Below is given a comparison of the qualities of this cylinder and of the steel tube and jacket in the 9-inch converted gun:

[All specimens cut longitudinally.]

Specimens.	Whence taken.	Length.	Density.	Tenacity per square inch.	Extension per inch in length at 50,000 pounds per square inch applied.	Restoration per inch in length for 50,000 pounds per square inch applied.	Permanent set for 50,000 pounds per square inch applied.	Elastic limit.
		Inches.		*Pounds.*				*Pounds.*
Bochum cylinder	Exterior	10	7.8481	57,500	0.05982	0.00200	0.05782	15,000
Steel tube	....do	10	7.8634	73,000	0.02190	0.00260	0.01930	25,000
Do	....do	10	7.8634	72,000	0.02100	0.00200	0.01900	23,000
Do	....do	10	7.8794	74,000	0.01900	0.00170	0.01730	25,000
Bochum cylinder	Interior	10	7.8481	53,400	0.09565	0.00230	0.09335	*7,000
Steel jacket	....do	5	7.8718	64,000	0.03800	0.00200	0.03500	19,000

* Permanent set of 0.00001 only from 7,000 up to 20,000 pounds.

The elastic limit of the steel tube is thus seen to be considerably higher than that of the Bochum sample. It also possesses a higher density and greater tensile strength, but *less extensibility.*

TABLE No. 1.

Relative diameters of the interior of the steel jacket and that portion of the steel tube over which it was shrunk, used in the conversion of 10-inch smooth-bore gun into 9-inch rifle.

Inches from front end of jacket.	Interior diameter of jacket.	Exterior diameter of tube.	Difference.	Half difference, or surplus metal.	Inches from front end of jacket.	Interior diameter of jacket.	Exterior diameter of tube.	Difference.	Half difference, or surplus metal.
44	13.215	13.221	0.006	0.0030	22	13.217	13.221	0.004	0.0020
43	13.215	13.221	0.006	0.0030	21	13.217	13.221	0.004	0.0020
42	13.215	13.221	0.006	0.0030	20	13.216	13.221	0.005	0.0025
41	13.215	13.221	0.006	0.0030	19	13.216	13.221	0.005	0.0025
40	13.216	13.221	0.005	0.0025	18	13.216	13.221	0.005	0.0025
39	13.216	13.221	0.005	0.0025	17	13.216	13.221	0.005	0.0025
38	13.216	13.221	0.005	0.0025	16	13.216	13.221	0.005	0.0025
37	13.216	13.221	0.005	0.0025	15	13.216	13.221	0.005	0.0025
36	13.216	13.221	0.005	0.0025	14	13.216	13.221	0.005	0.0025
35	13.216	13.221	0.005	0.0025	13	13.216	13.221	0.005	0.0025
34	13.216	13.221	0.005	0.0025	12	13.216	13.221	0.005	0.0025
33	13.216	13.221	0.005	0.0025	11	13.216	13.221	0.005	0.0025
32	13.216	13.221	0.005	0.0025	10	13.216	13.220	0.004	0.0020
31	13.216	13.221	0.005	0.0025	9	13.216	13.220	0.004	0.0020
30	13.217	13.221	0.004	0.0020	8	13.217	13.220	0.003	0.0015
29	13.217	13.221	0.004	0.0020	7	13.217	13.220	0.003	0.0015
28	13.217	13.221	0.004	0.0020	6	13.217	13.220	0.003	0.0015
27	13.217	13.221	0.004	0.0020	5	13.217	13.221	0.004	0.0020
26	13.217	13.221	0.004	0.0020	4	13.217	13.221	0.004	0.0020
25	13.217	13.221	0.004	0.0020	3	13.217	13.221	0.004	0.0020
24	13.217	13.221	0.004	0.0020	2	13.217	13.221	0.004	0.0020
23	13.217	13.221	0.004	0.0020	1	13.217	13.221	0.004	0.0020

TABLE No. 2.

Relative diameters of the interior of the cast-iron body, and exterior of the united tube and jacket for insertion therein, 9-inch steel-lined converted rifle.

Large part of bore, back of trunnions.					Small part of bore, back of trunnions.				
Inches from face of breech.	Interior diameter of gun.	Exterior diameter of jacket.	Difference.	Half difference, or surplus metal.	Inches from face of muzzle.	Interior diameter of gun.	Exterior diameter of tube.	Difference.	Half difference, or surplus metal.
56	17.3465	17.3532	0.0067	0.00335	1	13.1970	13.1900	−0.0070	.....
55	17.3470	17.3532	0.0062	0.00310	2	13.1970	13.1900	−0.0070	.....
54	17.3480	17.3532	0.0052	0.00260	4	13.1970	13.1900	−0.0070	.....
53	17.3480	17.3532	0.0052	0.00260	9	13.1970	13.1900	−0.0070	.....
52	17.3470	17.3530	0.0060	0.00300	8	13.1970	13.1000	−0.0070	.....
51	17.3470	17.3530	0.0060	0.00300	10	13.1970	13.1900	−0.0870	.....
50	17.3470	17.3530	0.0060	0.00300	12	13.1970	13.1900	−0.0070	.....
49	17.3470	17.3530	0.0060	0.00300	14	13.1970	13.1900	−0.0070	.....
48	17.3470	17.3530	0.0060	0.00300	16	13.1970	13.1970	−0.0070	.....
47	17.3470	17.3530	0.0060	0.00300	18	13.1970	13.1970	−0.0070	.....
46	17.3470	17.3530	0.0060	0.00300	20	13.1975	13.1900	−0.0075	.....
45	17.3470	17.3530	0.0060	0.00300	22	13.1975	13.1950	−0.0025	.....

TABLE No. 2—Continued.

Relative diameters of the interior of the cast-iron body, and exterior of the united tube and jacket for insertion therein, 9-inch steel-lined converted rifle.

Large part of bore, back of trunnions.					Small part of bore, back of trunnions.				
Inches from face of breech.	Interior diameter of gun.	Exterior diameter of jacket.	Difference.	Half difference, or surplus metal.	Inches from face of muzzle.	Interior diameter of gun.	Exterior diameter of tube.	Difference.	Half difference or surplus metal.
44	17.3470	47.3530	0.0060	0.00300	24	13.1980	13.1950	−0.0030	.....
43	17.3470	17.3530	0.0060	0.00300	26	13.1980	13.1950	−0.0030	.....
42	17.3470	17.3530	0.0060	0.00300	28	13.1980	13.1950	−0.0030	.....
41	17.3475	17.3532	0.0057	0.00285	30	13.1980	13.1970	−0.0010	.....
40	17.3475	17.3532	0.0057	0.00285	32	13.1980	13.1970	−0.0010	.....
39	17.3475	17.3532	0.0057	0.00285	34	13.1980	13.1980	0.0000	.....
38	17.3475	17.3532	0.0057	0.00285	36	13.1980	13.1980	0.0000	0.00000
37	17.3475	17.3532	0.0057	0.00285	38	13.1980	13.2000	0.0020	0.00100
36	17.3475	17.3532	0.0057	0.00285	40	13.1970	13.2000	0.0030	0.00150
35	17.3470	17.3535	0.0065	0.50325	42	13.1970	13.2000	0.0030	0.00150
34	17.3470	17.3535	0.0065	0.00325	44	13.1970	13.2000	0.0030	0.00150
33	17.3470	17.3535	0.0065	0.00325	46	13.1970	13.2000	0.0030	0.00150
32	17.3470	17.3535	0.0065	0.00325	48	13.1970	13.2000	0.0030	0.00150
31	17.3470	17.3535	0.0065	0.00325	50	13.1970	13.2020	0.0050	0.00250
30	17.3470	17.3535	0.0065	0.00325	51	13.1970	13.2020	0.0050	0.00250
29	17.3370	17.3535	0.0065	0.00325	52	13.1970	13.2020	0.0050	0.00250
28	17.3470	17.3532	0.0062	0.00310	53	13.1965	13.2020	0.0055	0.00275
27	17.3470	17.3532	0.0062	0.00310	54	13.1965	13.2020	0.0055	0.00275
26	17.3470	17.3532	0.0062	0.00310	55	13.1970	13.2020	0.0050	0.00250
25	17.3470	17.3532	0.0062	0.00310	56	13.1970	13.2030	0.0060	0.00300
24	17.3470	17.3532	0.0062	0.00310	57	13.1970	13.2030	0.0060	0.00300
23	17.3470	17.3532	0.0062	0.00310	58	13.1970	13.2030	0.0060	0.00300
22	17.3470	17.3532	0.0062	0.00310	59	13.1970	13.2030	0.0060	0.00300
21	17.3470	17.3530	0.0060	0.00300	60	13.1970	13.2030	0.0060	0.00300
20	17.3470	17.3530	0.0060	0.00300	61	13.1970	13.2030	0.0060	0.00300
19	17.3470	17.3530	0.0060	0.00300	62	13.1970	13.2030	0.0060	0.00300
18	17.3470	17.3530	0.0060	0.00300	63	13.1970	13.2030	0.0060	0.00300
17	17.3470	17.3530	0.0060	0.00300	64	13.1970	13.2030	0.0060	0.00300
16	17.3470	17.3530	0.0060	0.00300	65	13.1970	13.2030	0.0060	0.00300
15	17.3470	17.3530	0.0060	0.00300	66	13.1970	13.2025	0.0055	0.00275
14	17.3470	Commencement of breech screw-thread.			67	13.1970	13.2025	0.0055	0.00275
					68	13.1970	13.2025	0.0055	0.00275
13	17.3470	The superior diameter of the screw-thread of the steel jacket was about 0.004 inch less than that of the female screw in the cast-iron body.			69	13.1570	13.2025	0.0055	0.00275
12	17.3470				70	13.1970	13.2025	0.0055	0.00275
11	17.3470				71	13.1970	13.2025	0.0055	0.00275
10	17.3470				72	13.1970	13.2025	0.0055	0.00275
9	17.3470				73	13.1970	13.2025	0.0055	0.00275
8	17.3480				74	13.1970	13.2025	0.0055	0.00275
7	17.3480				75	13.1970	13.2025	0.0055	0.00275
6	17.3480				76	13.1970	13.2030	0.0060	0.00300
5	17.3480				76.50	13.1970	13.2030	0.0060	0.00300
4	17.3480								
3	17.3490								
2	17.3500								
1	17.3500								

TABLE NO. 4.—SPECIMEN NO. 1, (STEEL TUBE.)

Table showing the extension, restoration, and permanent set, caused by the undermen weights, per square inch of section, acting upon a solid cylinder ten inches long (b shoulders) and 0″.649 in diameter, taken from the exterior of the steel tube used conversion of a 10-inch smooth-bore gun into a 9-inch rifle. Specimen cut longitud and from a position opposite the charge.

Weight per square inch of section.	Extension per inch in length.	First difference.	Restoration per inch in length. A – B.	First difference.	Permanent set per inch in length.	First enc
Pounds.						
1,510	0.00002	.....	0.00002	.....	0.00000	0.
3,025	0.00015	0.00013	0.00015	0.00013	0.00000	0.
4,535	0.00035	0.00020	0.00035	0.00020	0.00000	0.
6,045	0.00040	0.00005	0.00040	0.00005	0.00000	0.
7,560	0.00043	0.00003	0.00043	0.00003	0.00000	0.
9,070	0.00046	0.00003	0.00046	0.00003	0.00000	0.
10,580	0.00049	0.00003	0.00049	0.00003	0.00000	0.
12,190	0.00053	0.00004	0.00053	0.00004	0.00000	0.
13,600	0.00059	0.00006	0.00059	0.00006	0.00000	0.
15,115	0.00065	0.00006	0.00065	0.00006	0.00000	0.
16,625	0.00070	0.00005	0.00070	0.00004	0.00000	0.
18,135	0.00074	0.00004	0.00074	0.00004	0.00000	0.
19,650	0.00080	0.00006	0.00080	0.00006	0.00000	0.
21,160	0.00085	0.00005	0.00085	0.00005	0.00000	0.
22,670	0.00090	0.00005	0.00090	0.00005	0.00000	0.
24,185	0.00095	0.00005	0.00095	0.00005	0.00000	0.
25,695	0.00102	0.00007	0.00101	0.00006	0.00001	0.
27,205	0.00108	0.00006	0.00107	0.00006	0.00001	0.
28,720	0.00114	0.00006	0.00112	0.00005	0.00002	0.
30,230	0.00123	0.00009	0.00115	0.00003	0.00008	0.
31,740	0.00130	0.00007	0.00113	– 0.00002	0.00017	0.
33,250	0.00140	0.00010	0.00116	0.00003	0.00024	0.
34,765	0.00255	0.00115	0.00074	– 0.00042	0.00181	0.
36,275	0.00510	0.00255	0.00130	0.00056	0.00380	0.
37,785	0.00720	0.00210	0.00125	– 0.00005	0.00595	0.
39,300	0.00890	0.00170	0.00130	0.00005	0.00760	0.
40,810	0.01095	0.00205	0.00155	0.00025	0.00940	0.
42,320	0.01156	0.00061	0.00155	0.00000	0.01001	0.
43,830	0.01545	0.00389	0.00385	0.00230	0.01160	0.
45,345	0.01755	0.00210	0.00160	0.00225	0.01595	0.
46,855	0.02130	0.00375	0.00270	0.00110	0.01860	0.
48,365	0.02180	0.00050	0.00260	– 0.00010	0.01920	0.
49,880	0.02190	0.00010	0.00260	0.00000	0.01930	0.
51,390	0.02190	0.00000	0.00235	– 0.00025	0.01955	0.
52,900	0.02195	0.00005	0.00215	– 0.00020	0.01980	0.
54,410	0.02200	0.00005	0.00210	0.00075	0.01990	0.
55,925	0.03030	0.00830	0.00265	– 0.00025	0.02765	0.
57,435	0.03535	0.00505	0.00230	– 0.00035	0.03205	0.
58,950	0.03905	0.00370	0.00225	– 0.00005	0.03680	0.
60,460	0.04470	0.00565	0.00310	0.00085	0.04160	0.
61,970	0.04880	0.00410	0.00265	– 0.00045	0.04615	0.
63,480	0.04890	0.00010	0.00265	0.00000	0.04625	0.
64,995	0.06635	0.01745	0.00290	0.00025	0.06345	0.
66,505	0.07606	0.00971	0.00181	– 0.00109	0.07425	0.

TABLE NO. 4.—SPECIMEN NO. 1, (STEEL TUBE)—Continued.

Weight per square inch of section.	Extension per inch in length.	First difference.	Restoration per inch in length. A—B.	First difference.	Permanent set per inch in length.	First difference.
Pounds.						
68,015	0.07620	0.00014	0.00180	—0.00001	0.07440	0.00015
69,525	0.07630	0.00010	0.00186	0.00016	0.07444	0.00004
71,040	0.07655	0.00025	0.00225	—0.00071	9.07430	0.00096
72,550	0.07715	0.00060	0.00200	—0.00025	0.07515	0.00085
74,060*						
75,575						

* Specimen broke below 74,000 pounds.

Specimen No. 1.

Specific gravity	7.8634	Tensile strength, pounds, per square inch	73,000
Original diameter	0″.649	Total elongation	1″.222
Diameter after 45,000 pounds per square inch	0″.642	Elongation per inch, (absolute)	0″.1222
Diameter at point of rupture	0″.490	Position of rupture, from end	1″.50
		Character of rupture	Drawn.

TABLE NO. 5.—SPECIMEN NO. 2, (STEEL TUBE.)

Table showing the extension, restoration, and permanent set, caused by the undermentioned weights, per square inch of section, acting upon a solid cylinder ten inches long (between shoulders) and 0″.649 in diameter, taken from the exterior of the steel tube used in the conversion of a 10-inch smooth-bore gun into a 9-inch rifle. Specimen cut longitudinally, and from a position opposite the charge.

Weight per square inch of section.	Extension per inch in length.	First difference.	Restoration per inch in length, A—B.	First difference.	Permanent set per inch in length.	First difference.
Pounds.						
1,510	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3,025	0.00005	0.00005	0.00005	0.00005	0.00000	0.00000
4,535	0.00010	0.00005	0.00010	0.00005	0.00000	0.00000
6,045	0.00020	0.00010	0.00020	0.00010	0.00000	0.00000
7,560	0.00030	0.00010	0.00034	0.00014	0.00000	0.00000
9,070	0.00034	0.00004	0.00035	0.00001	0.00000	0.00000
10,580	0.00035	0.00001	0.00035	0.00000	0.00000	0.00000
12,190	0.00040	0.00005	0.00040	0.00005	0.00000	0.00000
13,600	0.00045	0.00005	0.00045	0.00005	0.00000	0.00000
15,115	0.00050	0.00005	0.00050	0.00005	0.00000	0.00000
16,625	0.00055	0.00005	0.00055	0.00005	0.00000	0.00000
18,135	0.00062	0.00007	0.00060	0.00005	0.00000	0.00000
19,650	0.00070	0.00008	0.00070	0.00010	0.00000	0.00000
21,160	0.00078	0.00008	0.00078	0.00008	0.00000	0.00000
22,670	0.00083	0.00005	0.00083	0.00005	0.00000	0.00000
24,185	0.00086	0.00003	0.00084	0.00001	0.00002	0.00002
25,695	0.00088	0.00002	0.00084	0.00000	0.00004	0.00002
27,205	0.00090	0.00002	0.00085	0.00001	0.00005	0.00001
28,720	0.00098	0.00008	0.00093	0.00005	0.00005	0.00000
30,230	0.00110	0.00012	0.00105	0.00012	0.00005	0.00000
31,740	0.00115	0.00005	0.00110	—0.00007	0.00005	0.00000

TABLE NO. 5.—SPECIMEN NO. 2, (STEEL TUBE)—Continued.

Weight per square inch of section.	Extension per inch in length.	First difference.	Restoration per inch in length, A—B.	First difference.	Permanent set per inch in length.	First difference.
Pounds.						
33, 250	0. 00123	0. 00008	0. 00113	0. 00003	0. 00010	0. 00005
34, 765	0. 00154	0. 00031	0. 00114	0. 00023	0. 00040	0. 00030
36, 275	0. 00215	0. 00061	0. 00120	0. 00030	0. 00095	0. 00055
37, 785	0. 00530	0. 00315	0. 00138	0. 00254	0. 00392	0. 00297
39, 300	0. 00670	0. 00140	0. 00140	— 0. 00175	0. 00530	0. 00138
40, 810	0. 00918	0. 00248	0. 00198	— 0. 00108	0. 00720	0. 00210
42, 320	0. 01065	0. 00247	0. 00165	— 0. 00001	0. 00900	0. 00180
43, 830	0. 01300	0. 00235	0. 00120	— 0. 00012	0. 01180	0. 00280
45, 345	0. 01500	0. 00200	0. 00175	— 0. 00035	0. 01325	0. 00145
46, 855	0. 01770	0. 00270	0. 00195	— 0. 00070	0. 01575	0. 00250
48, 365	0. 02050	0. 00280	0. 00180	0. 00010	0. 01870	0. 00295
49, 880	0. 02080	0. 00030	0. 00165	0. 00015	0. 01905	0. 00035
51, 390	0. 02205	0. 00125	0. 00285	0. 00120	0. 01920	0. 00015
52, 900	0. 02220	0. 00015	0. 00192	0. 00093	0. 02028	0. 00108
54, 410	0. 02230	0. 00010	0. 00190	0. 00002	0. 02040	0. 00012
55, 925	0. 02740	0. 00510	0. 00205	0. 00015	0. 02535	0. 00495
57, 435	0. 03195	0. 00450	0. 00205	0. 00000	0. 02990	0. 00455
58, 950	0. 03785	0. 00590	0. 00240	0. 00035	0. 03545	0. 00555
60, 460	0. 04150	0. 00365	0. 00240	0. 00000	0. 03910	0. 00355
61, 970	0. 04650	0. 00500	0. 00240	0. 00000	0. 04410	0. 00500
63, 480	0. 05370	0. 00720	0. 00260	0. 00020	0. 05110	0. 00700
64, 995	0. 06207	0. 00837	0. 00287	0. 00027	0. 05920	0. 00810
66, 505	0. 07175	0. 00968	0. 00285	0. 00002	0. 06890	0. 00970
68, 015	0. 07200	0. 00025	0. 00240	— 0. 00045	0. 06960	0. 00070
69, 525	0. 07250	0. 00050	0. 00285	0. 00045	0. 06965	9. 00005
71, 040	0. 07300	0. 00050	0. 00270	— 0. 00015	0. 07030	0. 00065
72, 550*						
74, 060						
75, 575						

* Specimen broke below 72,500 pounds.

Specimen No. 2.

Specific gravity	7. 8634	Tensile strength, per square inch. pounds.	72, 000
Original diameter	0″. 649	Total elongation	1″. 650
Diameter after 45,000 pounds per square inch	0″. 642	Elongation per inch, (absolute)	0″. 165
Diameter at point of rupture	0″. 476	Position of rupture	Middle
		Character of rupture	Drawn

TABLE No. 6.—SPECIMEN No. 3, (STEEL TUBE.)

Table showing the extension, restoration, and permanent set caused by the undermentioned weights, per square inch of section, acting upon a solid cylinder, 10 inches long (between shoulders) and 0.649″ in diameter, taken from the exterior of the steel tube used in the conversion of a 10-inch smooth-bore gun into a 9-inch rifle. Specimen cut longitudinally, and from a position opposite the charge.

Weight per square inch of section in pounds.	Extension per inch in length.	First difference.	Restoration per inch in length. A—B.	First difference.	Permanent set per inch in length.	First difference.
1,510	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3,025	0.00002	0.00002	0.00002	0.00002	0.00000	0.00000
4,535	0.00005	0.00003	0.00005	0.00003	0.00000	0.00000
6,045	0.00005	0.00000	0.00005	0.00000	0.00000	0.00000
7,560	0.00010	0.00005	0.00010	0.00005	0.00000	0.00000
9,070	0.00020	0.00010	0.00020	0.00010	0.00000	0.00000
10,580	0.00030	0.00010	0.00030	0.00010	0.00000	0.00000
12,190	0.00030	0.00000	0.00030	0.00000	0.00000	0.00000
13,600	0.00038	0.00008	0.00038	0.00008	0.00000	0.00000
15,115	0.00045	0.00007	0.00045	0.00007	0.00000	0.00000
16,625	0.00052	0.00007	0.00052	0.00007	0.00000	0.00000
18,135	0.00056	0.00004	0.00056	0.00004	0.00000	0.00000
19,650	0.00059	0.00003	0.00059	0.00003	0.00000	0.00000
21,160	0.00063	0.00004	0.00063	0.00004	0.00000	0.00000
22,670	0.00066	0.00003	0.00066	0.00003	0.00000	0.00000
24,185	0.00075	0.00009	0.00075	0.00009	0.00000	0.00000
25,695	0.00078	0.00003	0.00078	0.00003	0.00000	0.00000
27,205	0.00082	0.00004	0.00080	0.00002	0.00002	0.00002
28,720	0.00090	0.00008	0.00088	0.00008	0.00002	0.00000
30,230	0.00095	0.00005	0.00091	0.00003	0.00004	0.00002
31,740	0.00102	0.00007	0.00096	0.00005	0.00006	0.00002
33,250	0.00114	0.00012	0.00098	0.00002	0.00016	0.00010
34,765	0.00140	0.00026	0.00070	0.00002	0.00070	0.00054
36,275	0.00190	0.00050	0.00116	0.00046	0.00074	0.00004
37,785	0.00245	0.00055	0.00125	0.00009	0.00120	0.00046
39,300	0.00585	0.00340	0.00135	0.00010	0.00450	0.00330
40,810	0.00720	0.00135	0.00130	—0.00005	0.00590	0.00120
42,320	0.00885	0.00165	0.00165	0.00035	0.00720	0.00130
43,830	0.01115	0.00230	0.00155	—0.00005	0.00960	0.00240
45,345	0.01305	0.00290	0.00170	0.00015	0.01135	0.00175
46,855	0.01520	0.00215	0.00149	—0.00021	0.01371	0.00236
48,365	0.01770	0.00250	0.00163	0.00014	0.01677	0.00236
49,880	0.01805	0.00035	0.00160	—0.00003	0.01645	0.00038
51,390	0.01915	0.00110	0.00180	0.00020	0.01735	0.00090
52,900	0.01972	0.00057	0.00190	0.00010	0.01782	0.00047
54,410	0.02020	0.00048	0.00205	0.00015	0.01815	0.00033
55,925	0.02876	0.00856	0.00215	0.00010	0.02661	0.00846
57,435	0.03274	0.00398	0.00228	0.00013	0.03046	0.00385
58,950	0.03600	0.00326	0.00220	—0.00008	0.03380	0.00334
60,460	0.03973	0.00373	0.00220	0.00000	0.03753	0.00373
61,970	0.04360	0.00387	0.00225	—0.00005	0.04135	0.00382
63,480	0.05015	0.00555	0.00235	0.00010	0.04780	0.00645
64,995	0.05746	0.00731	0.00363	0.00128	0.05383	0.00603
66,505	0.06883	0.01137	0.00553	0.00190	0.06330	0.00947
68,015	0.08250	0.01367	0.00583	0.00030	0.07667	0.00337
69,525	0.08356	0.00106	0.00390	—0.00193	0.07966	0.00301
71,040	0.08365	0.00009	0.00290	—0.00100	0.08075	0.00109
72,550	0.08398	0.00033	0.00285	—0.00005	0.08113	0.00038
74,060	0.08449	0.00051	0.00290	0.00005	0.08159	0.00046
75,575	Specimen broke below 75,500 pounds.					

TABLE NO. 5.—SPECIMEN NO. 2, (STEEL TUBE)—Continued.

Weight per square inch of section.	Extension per inch in length.	First difference.	Restoration per inch in length, A—B.	First difference.	Permanent set per inch in length.	First enc
Pounds.						
33, 250	0. 00123	0. 00008	0. 00113	0. 00003	0. 00010	0
34, 765	0. 00154	0. 00031	0. 00114	0. 00023	0. 00040	0
36, 275	0. 00215	0. 00061	0. 00120	0. 00030	0. 00095	0
37, 785	0. 00530	0. 00315	0. 00138	0. 00254	0. 00392	0
39, 300	0. 00670	0. 00140	0. 00140	— 0. 00175	0. 00530	0
40, 810	0. 00918	0. 00248	0. 00198	— 0. 00108	0. 00720	0
42, 320	0. 01065	0. 00247	0. 00165	— 0. 00001	0. 00900	0
43, 830	0. 01300	0. 00235	0. 00120	— 0. 00012	0. 01180	0
45, 345	0. 01500	0. 00200	0. 00175	— 0. 00035	0. 01325	0
46, 855	0. 01770	0. 00270	0. 00195	— 0. 00070	0. 01575	0
48, 365	0. 02050	0. 00280	0. 00180	0. 00010	0. 01870	0
49, 880	0. 02080	0. 00030	0. 00165	0. 00015	0. 01905	0
51, 390	0. 02205	0. 00125	0. 00285	0. 00120	0. 01920	0
52, 900	0. 02220	0. 00015	0. 00192	0. 00093	0. 02028	0
54, 410	0. 02230	0. 00010	0. 00190	0. 00002	0. 02040	0
55, 925	0. 02740	0. 00510	0. 00205	0. 00015	0. 02535	0
57, 435	0. 03195	0. 00450	0. 00205	0. 00000	0. 02990	0
58, 950	0. 03785	0. 00590	0. 00240	0. 00035	0. 03545	0
60, 460	0. 04150	0. 00365	0. 00240	0. 00000	0. 03910	0
61, 970	0. 04650	0. 00500	0. 00240	0. 00000	0. 04410	0
63, 480	0. 05370	0. 00720	0. 00260	0. 00020	0. 05110	0
64, 995	0. 06207	0. 00837	0. 00287	0. 00027	0. 05920	0
66, 505	0. 07175	0. 00968	0. 00285	0. 00002	0. 06890	0
68, 015	0. 07200	0. 00025	0. 00240	— 0. 00045	0. 06960	0
69, 525	0. 07250	0. 00050	0. 00285	0. 00045	0. 06965	9
71, 040	0. 07300	0. 00050	0. 00270	— 0. 00015	0. 07030	0
72, 550*						
74, 060						
75, 575						

* Specimen broke below 72,500 pounds.

Specimen No. 2.

Specific gravity	7. 8634	Tensile strength, per square inch. pounds.	
Original diameter	0″. 649	Total elongation	
Diameter after 45,000 pounds per square inch	0″. 642	Elongation per inch, (absolute)	
Diameter at point of rupture	0″. 476	Position of rupture	1
		Character of rupture	I

TABLE No. 6.—SPECIMEN No. 3, (STEEL TUBE.)

Table showing the extension, restoration, and permanent set caused by the undermentioned weights, per square inch of section, acting upon a solid cylinder, 10 inches long (between shoulders) and 0.649″ in diameter, taken from the exterior of the steel tube used in the conversion of a 10-inch smooth-bore gun into a 9-inch rifle. Specimen cut longitudinally, and from a position opposite the charge.

Weight per square inch of section in pounds.	Extension per inch in length.	First difference.	Restoration per inch in length. A—B.	First difference.	Permanent set per inch in length.	First difference.
1,510	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3,025	0.00002	0.00002	0.00002	0.00002	0.00000	0.00000
4,535	0.00005	0.00003	0.00005	0.00003	0.00000	0.00000
6,045	0.00005	0.00000	0.00005	0.00000	0.00000	0.00000
7,560	0.00010	0.00005	0.00010	0.00005	0.00000	0.00000
9,070	0.00020	0.00010	0.00020	0.00010	0.00000	0.00000
10,580	0.00030	0.00010	0.00030	0.00010	0.00000	0.00000
12,190	0.00030	0.00000	0.00030	0.00000	0.00000	0.00000
13,600	0.00038	0.00008	0.00038	0.00008	0.00000	0.00000
15,115	0.00045	0.00007	0.00045	0.00007	0.00000	0.00000
16,625	0.00052	0.00007	0.00052	0.00007	0.00000	0.00000
18,135	0.00056	0.00004	0.00056	0.00004	0.00000	0.00000
19,650	0.00059	0.00003	0.00059	0.00003	0.00000	0.00000
21,160	0.00063	0.00004	0.00063	0.00004	0.00000	0.00000
22,670	0.00066	0.00003	0.00066	0.00003	0.00000	0.00000
24,185	0.00075	0.00009	0.00075	0.00009	0.00000	0.00000
25,695	0.00078	0.00003	0.00078	0.00003	0.00000	0.00000
27,205	0.00082	0.00004	0.00080	0.00002	0.00002	0.00002
28,720	0.00090	0.00008	0.00088	0.00008	0.00002	0.00000
30,230	0.00095	0.00005	0.00091	0.00003	0.00004	0.00002
31,740	0.00102	0.00007	0.00096	0.00005	0.00006	0.00002
33,250	0.00114	0.00012	0.00098	0.00002	0.00016	0.00010
34,765	0.00140	0.00026	0.00070	0.00002	0.00070	0.00054
36,275	0.00190	0.00050	0.00116	0.00046	0.00074	0.00004
37,785	0.00245	0.00055	0.00125	0.00009	0.00120	0.00046
39,300	0.00585	0.00340	0.00135	0.00010	0.00450	0.00330
40,810	0.00720	0.00135	0.00130	—0.00005	0.00590	0.00120
42,320	0.00885	0.00165	0.00165	0.00035	0.00720	0.00130
43,830	0.01115	0.00230	0.00155	—0.00005	0.00960	0.00240
45,345	0.01305	0.00290	0.00170	0.00015	0.01135	0.00175
46,855	0.01520	0.00215	0.00149	—0.00021	0.01371	0.00236
48,365	0.01770	0.00250	0.00163	0.00014	0.01677	0.00236
49,880	0.01805	0.00035	0.00160	—0.00003	0.01645	0.00038
51,390	0.01915	0.00110	0.00180	0.00020	0.01735	0.00090
52,900	0.01972	0.00057	0.00190	0.00010	0.01782	0.00047
54,410	0.02020	0.00048	0.00205	0.00015	0.01815	0.00033
55,925	0.02876	0.00856	0.00215	0.00010	0.02661	0.00846
57,435	0.03274	0.00398	0.00228	0.00013	0.03046	0.00385
58,950	0.03600	0.00326	0.00220	—0.00008	0.03380	0.00334
60,460	0.03973	0.00373	0.00220	0.00000	0.03753	0.00373
61,970	0.04360	0.00387	0.00225	—0.00005	0.04135	0.00382
63,480	0.05015	0.00555	0.00235	0.00010	0.04780	0.00645
64,995	0.05746	0.00731	0.00363	0.00128	0.05383	0.00603
66,505	0.06883	0.01137	0.00553	0.00190	0.06330	0.00947
68,015	0.08250	0.01367	0.00583	0.00030	0.07667	0.00337
69,525	0.08356	0.00106	0.00390	—0.00193	0.07966	0.00301
71,040	0.08365	0.00009	0.00290	—0.00100	0.08075	0.00109
72,550	0.08398	0.00033	0.00285	—0.00005	0.08113	0.00038
74,060	0.08449	0.00051	0.00290	0.00005	0.08159	0.00046
75,575	Specimen broke below 75,500 pounds.					

Specimen No. 3.

Specific gravity	7.8794	Tensile strength, pounds per square inch.	75,000
Orignal diameter	0″.649	Total elongation	1″.117
Diameter after, 45,000 pounds per square inch	0″.644	Elongation per inch, (absolute)	0″.1117
Diameter at point of rupture	0″.572	Position of rupture, (from end)	2″.5
		Character of rupture	Crystalline.

TABLE NO. 7.—SPECIMEN NO. 4, (STEEL JACKET.)

Table showing the extension, restoration, and permanent set caused by the undermentioned weights, per square inch of section, acting upon a solid cylinder, five inches long (between shoulders) and 0″.654 in diameter, taken from the center of the breech-end of the steel jacket used in the conversion of a 10-inch smooth-bore gun into a 9-inch rifle. Specimen cut longitudinally, and in a line with the axis of the bore.

Weight per square inch of section.	Extension per inch in length.	First difference.	Restoration per inch in length.	First difference.	Permanent set per inch in length.	First difference.
Pounds.						
1,500	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3,000	0.00006	0.00006	0.00006	0.00006	0.00000	0.00000
4,500	0.00014	0.00008	0.00014	0.00008	0.00000	0.00000
6,000	0.00016	0.00002	0.00016	0.00002	0.00000	0.00000
7,500	0.00020	0.00004	0.00020	0.00004	0.00000	0.00000
9,000	0.00026	0.00006	0.00026	0.00006	0.00000	0.00000
10,500	0.00030	0.00004	0.00030	0.00006	0.00000	0.00000
12,000	0.00034	0.00004	0.00034	0.00004	0.00000	0.00000
13,500	0.00040	0.00006	0.00040	0.00006	0.00000	0.00000
15,000	0.00056	0.00006	0.00056	0.00016	0.00000	0.00000
16,500	0.00064	0.00008	0.00064	0.00008	0.00000	0.00000
18,000	0.00066	0.00002	0.00066	0.00002	0.00000	0.00000
19,500	0.00068	0.00002	0.00066	0.00000	0.00002	0.00002
21,000	0.00070	0.00002	0.00068	0.00002	0.00002	0.00000
22,500	0.00072	0.00002	0.00068	0.00000	0.00004	0.00002
24,000	0.00074	0.00002	0.00068	0.00000	0.00006	0.00002
25,500	0.00076	0.00002	0.00070	0.00002	0.00006	0.00000
27,000	0.00082	0.00006	0.00072	—0.00002	0.00010	5.00004
28,500	0.00114	0.00032	0.00094	0.00022	0.00020	0.00010
30,000	0.00170	0.00056	0.00130	0.00036	0.00040	0.00020
31,500	0.00250	0.00080	0.00080	—0.00050	0.00170	0.00130
33,000	0.00460	0.00210	0.00060	—0.00020	0.00400	0.00230
34,500	0.00710	0.00250	0.00140	0.00080	0.00570	0.00170
36,000	0.00803	0.00093	0.00130	—0.00010	0.00673	0.00103
37,500	0.01140	0.00337	0.00190	—0.00060	0.00950	0.00277
39,000	0.01290	0.00150	0.00190	0.00000	0.01100	0.00150
40,500	0.01560	0.00270	0.00140	—0.00050	0.01420	0.00320
42,000	0.01850	0.00290	0.00150	0.00010	0.01700	0.00280
43,500	0.02070	0.00220	0.00160	0.00010	0.01910	0.00210
45,000	0.02232	0.00162	0.00160	0.00000	0.02070	0.00160
46,500	0.02760	0.00528	0.00180	0.00020	0.02580	0.00510
48,000	0.03130	0.00370	0.00190	0.00010	0.02940	0.00360
49,500	0.03620	0.00490	0.00250	0.00060	0.03370	0.00430
51,000	0.03940	0.00320	0.00180	0.00030	0.03760	0.00390
52,500	0.04422	0.00482	0.00230	0.00050	0.04192	0.00432
54,000	0.05190	0.00768	0.00220	—0.00010	0.04970	0.00778

TABLE No. 7.—SPECIMEN No. 4, (STEEL JACKET)—Continued.

Weight per square inch of section.	Extension per inch in length.	First difference.	Restoration per inch in length.	First difference.	Permanent set per inch in length.	First difference.
Pounds.						
55,500	0.05680	0.00490	0.00250	0.00030	0.05430	0.00460
57,000	0.06420	0.00740	0.00260	0.00010	0.06160	0.00730
58,500	0.07350	0.00930	0.00330	0.00070	0.07020	0.00860
60,000	0.08470	0.01120	0.00270	—0.00060	0.08200	0.01180
61,500	0.10110	0.01640	0.00304	0.00034	0.09906	0.01706
63,000	0.13240	0.03130	0.00370	0.00066	0.12870	0.02964
64,500	Specimen broke below 64,500 pounds. Small defect 0″.10 diameter at fracture.					

Specimen No. 4.

Specific gravity	7.8718	Total elongation	0″.740
Original diameter	0″.6515	Elongation per inch, (absolute)	0″.148
Diameter at point of rupture	0″.6100	Position of rupture	Near middle.
Smallest diameter	0″.6050	Character of rupture	Crystalline.
Tensile strength, pounds per square inch	64,000		

Full strength of specimen not developed, owing to slight blister at breaking point.

EXTRACT FROM A REPORT MADE BY CAPT. J. G. BUTLER, ORDNANCE CORPS, ON AN EXPERIMENTAL CAST-IRON CYLINDER SUBJECTED TO THE INFLUENCE OF HEAT.

"The experiments with the cast-iron cylinder have been very satisfactory, and I submit the following details thereof: These experiments were instituted not so much to ascertain the actual expansion of the cylinder due to a certain heat (this could be arrived at quite correctly by calculation) as to determine practically other conditions of expansion and contraction, as will be explained.

"The cast-iron cylinder ordered by you before I reported at this office was finished 10 inches in diameter of bore, 10 inches thickness of walls, and 50 inches in length, weighing, thus finished, 8,340 pounds.

"By your directions, the following was the composition of the metal used in casting the cylinder:

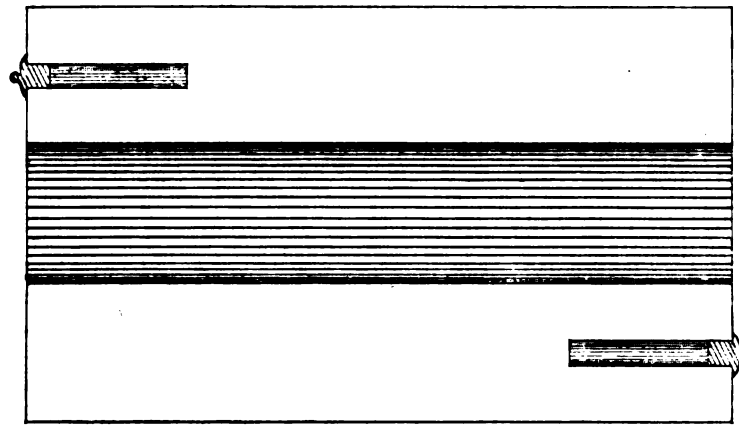
	Pounds.
No. 2 red soft	2,500
No. 2 red hard	2,500
No. 3 white	2,500
Nos. 1, 2, and 3 remelted	2,500

"Specimens taken from the sinking head of cylinder next to face of cutting gave the following results:

	Pounds.
No. 1.—Inside specimen, specific gravity, 7.31; tenacity	29,600
No. 2.—Middle specimen, specific gravity, 7.27; tenacity	31,600
No. 3.—Outside specimen, specific gravity, 7.31; tenacity	31,400

"As the most practical method of arriving correctly at the temperature of the mass, I had a hole 15 inches in depth and 1½ inches in diameter drilled in each end of the cylinder, as shown in the following sketch. These holes were of just sufficient size to accommodate a high-range thermometer, and were then stopped up with a close-fitting iron stopper.

"Thus deeply buried in the mass of the iron, and with outside air cluded, the correct temperature of the metal could be ascertained at a time within at least a close degree of approximation.



"In order, however, to avoid the risk of breaking the thermometer case too high a temperature should be attained, a cubic inch of le instead of the thermometer, was inserted in each pocket when the inder was placed in the furnace, the melting of the lead indicating t sufficient heat was attained. The cylinder was heated in an ordin air-furnace without blast, and with slight draught; wood was ex sively employed for fuel, and the draught so regulated that the fla surrounded the cylinder, in addition to which the precaution was adop of turning it several times to insure uniform heating. As the therm eter which I had constructed could range but little over 650° with danger of breaking, and as it was not thought that the gun would likely to be brought to any higher temperature than this for the in tion of the steel tube, it was intended to remove the cylinder as soor the lead in the closed pockets had melted, which would indicate a t perature between 644° and 700°. It was proposed to make two or th series of experiments, and if the wood furnace should prove in any unsatisfactory, to have a special furnace constructed. This, howe proved unnecessary.

FIRST EXPERIMENT.

"The thermometer not being ready, as promised, and the only one hand unfortunately breaking, it was determined to make a prelimin trial, testing the temperature by the melting-point of metals, using le which would melt at about 650°, and tin, the melting-point of wh reached 450°, for this purpose.

"Cylinder inserted in furnace, previously heated, at 11 a. m.

"Cylinder turned over at 12 m.

"Cylinder removed from furnace at 1 p. m.

"The cylinder was found hotter than intended, owing to neglect furnace-man to shut down draught.

"Edges of cylinder and one side, cherry-red.

"Temperature of cylinder on hottest side, about 1,100°.

"Temperature of cylinder on opposite side, 800°.

"After 30 minutes one cubic inch of lead melted on hot side in minutes, and on opposite side in two minutes. Continued to melt l

in the opposite ends and sides of cylinder for one hour, (cylinder gradually becoming of uniform temperature,) at end of which time a cubic inch of lead, in opposite sides, melted in equal times, namely, 4½ minutes. Lead in opposite sides continued to melt in equal times from this out. Melted lead at intervals of 15 minutes, until it required 7½ minutes to melt, when the cylinder was measured, with the result shown in the following table. When lead remained in ten minutes, and one-half melted, cylinder was again measured; 15 minutes after this measurement lead would not melt.

"Continued the experiment with tin in similar manner; and when a cubic inch of tin remained in eight minutes, and barely half-melted, consolidating in being scraped out, again measured cylinder.

"The cylinder was then allowed to cool during two nights and a day before the second experiment, and again measured, its temperature at this time being between 90 and 100 degrees; temperature of surrounding atmosphere, 75°.

Measurements of cylinder, first trial.

Number of inches from face of cylinder.	Measurement before inserting in furnace. Temperature of air 72°.	Measurement when lead melted in 7½ minutes, or say at 700°.	Measurement when lead only melted in 10 minutes, or say at 650°.	Measurement when tin only melted in 8 minutes, or say at 450°.	Measurement after 40 hours' cooling, or say at 100°.
2	10.000	10.040	10.036	10.020	10.002
4	10.000	.....	.....	.....	10.002
6	10.000	10.043	.....	.....	10.002
8	10.000	.....	.....	.....	10.002
10	10.000	10.045	.....	.....	10.002
12	10.000	.....	.....	.....	10.002
14	10.000	10.047	10.040	10.024	10.002
16	10.000	.....	.....	.....	10.002
18	10.000	10.048	.....	.....	10.002
20	10.000	.....	.....	.....	10.002
22	10.000	10.049	.....	.....	10.002
24	10.000	.....	.....	.....	10.002
25	10.000	10.050	10.045	10.026	10.002
26	10.000	.....	.....	.....	10.002
28	10.000	10.049	.....	.....	10.002
30	10.000	.....	.....	.....	10.002
32	10.000	10.048	.....	.....	10.002
34	10.000	.....	.....	.....	10.002
36	10.000	10.047	10.040	10.024	10.002
38	10.000	.....	.....	.....	10.002
40	10.000	10.045	.....	.....	10.002
42	10.000	.....	.....	.....	10.002
44	10.000	10.043	.....	.....	10.000
46	10.000	.....	.....	.....	10.002
48	10.000	10.040	10.036	10.020	10.002

"The above measurements were made with a star-gauge. It was found that six or eight measurements could be made before the points showed any expansion due to the heat; only three or four measurements, however, were made at one time; the gauge was then removed and verified,

the points dipped in water, wiped dry, and gauge verified again before insertion. The cylinder was gauged from the center outward toward each end; and it is not believed that there are any errors in the readings beyond the thousandth of an inch.

SECOND EXPERIMENT.

"During the interval while the cylinder was cooling the furnace was altered and much improved, so that the flames encircled the cylinder much farther and more uniformly. The cylinder was found not quite cold, although nearly so; and, having been heated more on one side than another, it was carefully measured along conjugate diameters to determine the important point as to whether the unequal heating had permanently affected its symmetry. Not the slightest variation, however, from a true cylinder could be detected in the bore. As shown in the table the cylinder had contracted .002 inch beyond its original caliber, and was not yet perfectly cold. No difference could be detected in the exterior diameter. A difference doubtless obtained, but the large calipers employed were not delicate enough to register it. For the same reason the difference in exterior diameters of middle and ends, when the cylinder was heated, could not be detected and was not deemed important.

"Cylinder inserted in cold furnace and fire started at..... 9.25 a. m.
"Cylinder turned at..... 10.00 a. m.
"Cylinder turned at..... 11.00 a. m.
"Cylinder removed at..... 11.15 a. m.

"The cylinder appeared to be uniformly heated, edges taking up heat more readily; were a very dull red.

"After an interval of thirty minutes a cubic inch of lead was found to be melted in two minutes. Lead was melted at intervals of fifteen minutes; time of melting on either side being the same, until after the lapse of an hour and a half. Between an interval when lead melted and would not melt the thermometer was inserted, and when registering its highest point, 650°, measurements were commenced. By closing the ends of the cylinder it was found that a thermometer placed in the middle of the bore registered the same as in the pockets, and towards the close of the experiments registered slightly more.

Measurements of cylinder, second trial.

Number of inches from face of cylinder.	Temperature of gun about 100°.	Temperature, bore, 650°; pockets, 650°.	Temperature, bore, 600°; pockets, 600°.	Temperature, bore, 550°; pockets, 550°.	Temperature, bore, 500°; pockets, 500°.	Temperature, bore, 450°; pockets, 445°.	Temperature, bore, 400°; pockets, 390°.	Temperature, bore, 375°; pockets, 360°.	Measurement after 70 hours' cooling, air, 70°.
2	10.002	10.032	10.029	10.026	10.023	10.020	10.016	10.014	10.005
4	10.002	.....	.....	.....	.....	.....	.....	.....	10.005
6	10.002	10.036	.....	.....	.....	.....	.....	.....	10.005
8	10.002	.....	.....	.....	.....	.....	.....	.....	10.005
10	10.002	10.038	10.033	10.029	10.026	10.022	10.018	10.016	10.005
12	10.002	.....	.....	.....	.....	.....	.....	.....	10.005
14	10.002	10.040	.....	.....	.....	.....	.....	.....	10.005
16	10.002	.....	.....	.....	.....	.....	.....	.....	10.005
18	10.002	10.041	10.036	10.031	10.028	10.024	10.020	10.018	10.005
20	10.002	.....	.....	.....	.....	.....	.....	.....	10.005
22	10.002	10.042	.....	.....	.....	.....	.....	.....	10.005
24	10.002	.....	.....	.....	.....	.....	.....	.....	10.005
25	10.002	10.042	10.038	10.033	10.030	10.026	10.022	10.019	10.005
26	10.002	.....	.....	.....	.....	.....	.....	.....	10.005
28	10.002	10.042	.....	.....	.....	.....	.....	.....	10.005
30	10.002	.....	.....	.....	.....	.....	.....	.....	10.005
32	10.002	10.041	10.036	10.031	10.028	10.024	10.020	10.018	10.005
34	10.002	.....	.....	.....	.....	.....	.....	.....	10.005
36	10.002	10.040	.....	.....	.....	.....	.....	.....	10.005
38	10.002	.....	.....	.....	.....	.....	.....	.....	10.005
40	10.002	10.038	10.033	10.029	10.026	10.022	10.018	10.016	10.005
42	10.002	.....	.....	.....	.....	.....	.....	.....	10.005
44	10.002	10.036	.....	.....	.....	.....	.....	.....	10.005
46	10.002	.....	.....	.....	.....	.....	.....	.....	10.005
48	10.002	10.032	10.029	10.026	10.023	10.020	10.016	10.014	10.005

"The above measurements may be relied upon generally to within the thousandth of an inch.

"When the cylinder was entirely cold, six days after the second trial, it was again measured horizontally and vertically as it lay, and was found to be absolutely true as far as measurements of considerable delicacy could detect.

"If we may conclude that the cylinder would have contracted one-thousandth of an inch more after the first experiment, if it had been allowed to become absolutely cold, it will be seen by a comparison of the two tables that the subsequent heating of the cylinder to a given temperature, brought it to the same degree of expansion, *less exactly the degree of previous contraction.* We may derive the following conclusions from the foregoing experiments:

First. The practical results obtained correspond closely with those by calculation, where it is found that the internal expansion of this cylinder would be about 0.0111 diametrically for every 180° F., or 100° C.

Second. That successive heatings to a given temperature will produce equal expansions, less each preceding ultimate contraction beyond original diameter.

Third. That immediately after removing the cylinder from the fur-

nace the ends are apt to be found hottest, giving to the right-line elements of the bore a slightly convex shape.

Fourth. That owing to the more rapid cooling of the ends, this condition of affairs is soon reversed, and the interior of the cylinder being at a higher temperature these lines become *concave*, the difference of radii of middle and extremities of bore being, in a cylinder of 50 inches length, 10 inches bore, and 30 inches exterior diameter; about 0.005 inch for 700°."

THE MOFFATT 3".07 BREECH-LOADING RIFLED FIELD-GUN.

This gun was fabricated and tested in conformity with section 1 of the act of Congress approved June 6, 1872. It was manufactured by the South Boston Iron Company under orders from this office, and under the immediate supervision of the inventor. It was completed and accepted about November 1, 1873, and up to date 175 rounds in all have been fired at various times, and it now awaits further tests; also competitive trials, contemplated by the Department, with other breech-loading systems for field service, now awaiting experiment.

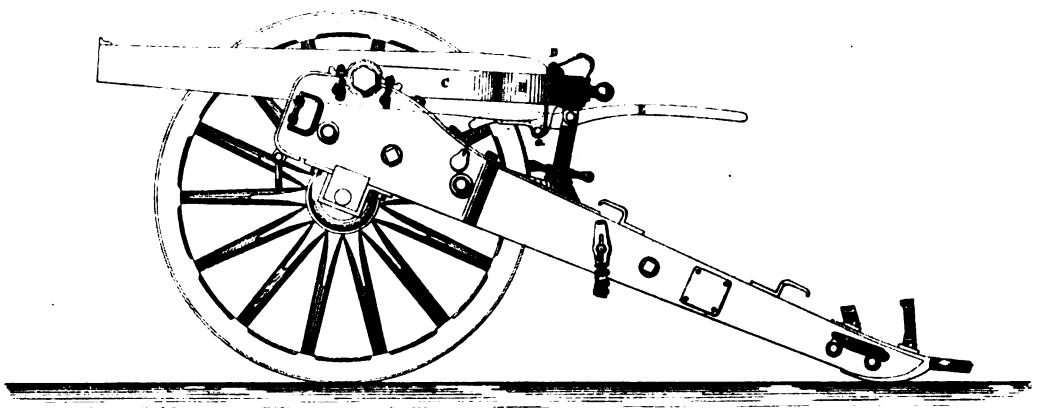
DESCRIPTION OF THE GUN.

Plate III, Fig. 1. The body A is of steel, and bored through from end to end. The breech-mechanism consists of a conical breech-plug D, accurately fitted to the bottom of the bore, and efficiently closing the same through the support afforded by the breech-strap B C, Fig. 2. This strap is attached to the trunnions as an axis of motion, but is enabled to withstand the strain of discharge by locking into lugs on either side of the breech of the gun. The breech-strap rests in rear upon the top of the elevating-screw, to which it is attached by a suitable coupling, to admit of the free movement of the screw. The breech-block is hinged in a fork attached to the under side of the breech. The operation of the mechanism is as follows: The breech is opened by tilting up the breech of the gun through the medium of a lever E, which has its axis in a stirrup underneath the breech-strap. By this operation the block is raised out of the breech-strap, and falls back by its own weight upon the latter, thus exposing the chamber. To close the breech again the lever is raised, and the gun, owing to its preponderance, falls back into the position for firing; the wedge-shaped back of the breech-block, at the same time, enters a correspondingly beveled recess in the breech-strap, and draws the latter firmly against the lugs, the loops of the strap over the trunnions admitting of a slight play for that purpose.

In the preliminary firings had with the gun, to test the working of the parts, the breech was thrown open by the shock of discharge, closing again during the recoil. To obviate this a locking device was added, consisting of a bolt and key, passing through the breech-strap and into a recess in the breech-block, in the manner shown in the figure. A half-turn of the handle is sufficient to press the block firmly down into place, and there retain it. A half-turn in a contrary direction disengages the key from the recess in the block, and the breech can be thrown open. Should the breech-block not always fall back on tilting up the breech, a leather strap is provided, attached as shown in the plate, which pulls back the block after the breech has been sufficiently raised to disengage it from the strap.

Plate I.

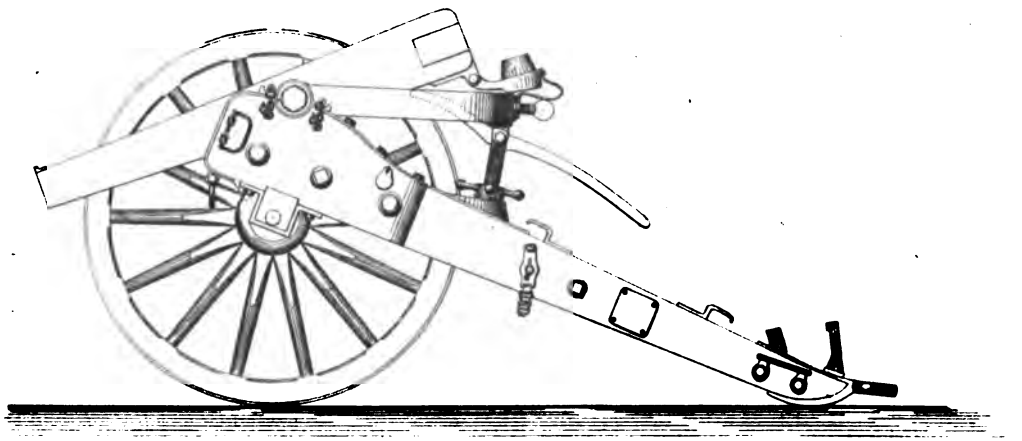
3.07 INCH MOFFATT BREECH LOADING FIELD PIECE.



A. Crispin
Bot Col Nav St Col of Ord
Constructor of Ord

Plate II.

3.07 INCH MOFFATT BREECHLOADING FIELD PIECE.



A. Crispin
Bt Col. U.S. Lt Col of Ord
Constructor of Ord

3.07 INCH MOFFATT BREECHLOADING FIELD PIECE.

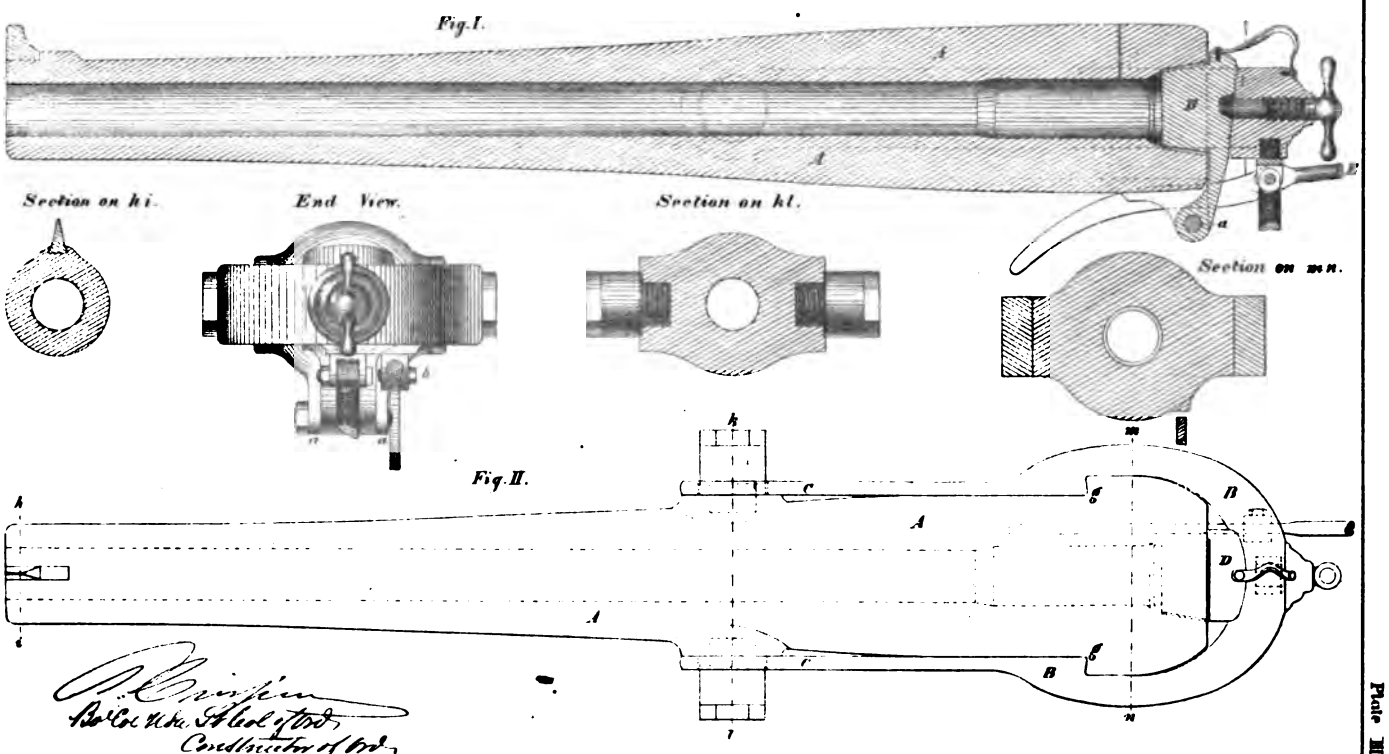
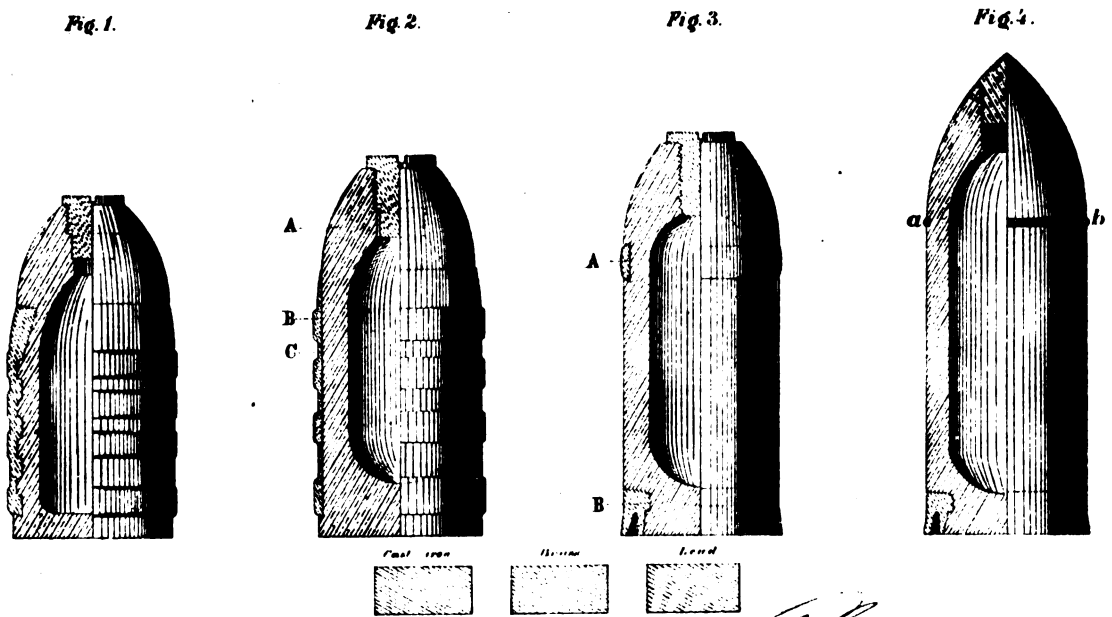


Plate III.

PROJECTILES FOR 3.07 INCH MOFFATT'S B.L. FIELD PIECE.



Bt Co. the Lt Co. of Ord
Constructor of Ord

The trunnions are screwed into the gun-body, and are furnished with shoulders, by which the loops of the breech-strap are closely confined to the rimbases.

RIFLING AND CHAMBERING.

The rifling of the gun consists of twelve grooves and lands each, the width of the lands being 0″.25, and the depth of the grooves 0″.05. The twist is uniform, and makes one turn in 12 feet. The chamber is concentric with the bore, but of larger diameter, measuring 3″.19, the diameter of the bore through grooves being but 3″.17. Its capacity is such as to accommodate a charge of 1¼ pounds of powder and a lead-coated or a double-bearing Butler projectile of about 10 pounds weight, the projectile being inserted in the rifled portion of the bore as far as the front rib or band.

The vent is in the normal position on top of the gun.

GAS-CHECKS.

When the gun was originally finished it was provided with a cup-shaped gas-check of copper; but having failed to give satisfaction under heavy charges, a number of Broadwell rings, of steel, brass, and composition, were tried, several of which gave excellent results.

PROJECTILES.

The projectiles proposed for trial with this gun are shown in Plate IV.

Figure 1 is a lead-coated projectile, in which the coating is attached by under-cuts on the cast-iron body of the projectile.

Figure 2 has the lead coating attached chemically to the body of the shot.

Figures 3 and 4 represent the Butler expansive projectile, in which rotation is intended to be conveyed by the double-lipped ring on the base of the projectile. The forward ring or band stops at the rifling of the bore, and centers the first portion of the projectiles; the lip, when fully expanded by the powder-gas, centering the rear. Weight of projectile, 9 pounds.

MEANS OF OBTAINING GAS PRESSURES.

The use of a loose internal Rodman pressure-gauge being precluded in a small breech-loader, and it not being wished to mar the gun by boring for the external gauge, the inner face of the breech-block was bored and tapped for the reception of an interior plug.

FABRICATION OF THE GUN.

The gun-body was manufactured by Messrs. Firth & Sons, Sheffield, England, of the best quality of crucible cast-steel, and forged from a single ingot. As received at the South Boston foundry, it was rough-bored and turned. The steel for the breech-block, strap, &c., were forgings obtained from the Nashua Works, New Hampshire. The final work of fitting, finishing, and assembling, was accomplished at the South Boston foundry, under the supervision of the inventor.

INSPECTION.

The gun showed good workmanship and finish.

DIMENSIONS, &C.

The following are the dimensions of its principal parts, to wit:

Diameter of bore across lands	3.07 inches.
Diameter of bore through grooves	3.17 inches.
Diameter of chamber	3.19 inches.
Diameter of breech-block cavity at seat of gas-check.	3.90 inches.
Diameter of breech-block cavity, outer edge	5.23 inches.
Diameter of piece at muzzle	5.90 inches.
Diameter of piece at trunnions	8 00 inches.
Diameter, maximum	9.57 inches.
Diameter of breech	9.57 inches.
Diameter of trunnions	3.67 inches.
Distance between rimbases	9.60 inches.
Distance between lugs	11.50 inches.
Distance between outside faces of breech-strap	14.20 inches.
Length of rifle portion of bore	55.00 inches.
Length of beveled junction of chamber and bore	1.00 inch.
Length of chamber	9.50 inches.
Total length of gun	72.65 inches.
Pitch of rifling uniform; one turn in	144.00 inches.
Number of grooves and lands	12
Width of lands	0.25 inch.
Weight of gun	1,000 pounds.
Weight of gun-carriage without implements	900 pounds.

The preponderance of the gun at the elevating-screw is such as to render the gun easily operated.

THE CARRIAGE.

The gun, upon completion, was mounted on a United States 6-pounder carriage; the only modifications required being to change the housing for the elevating-screw, and to slightly increase the space between the cheek-pieces.

Plate II shows the piece mounted on its carriage, and in a position for loading. Plate I shows breech apparatus closed and ready for firing.

EXPERIMENTS AND TESTS.

This gun has been fired at Sandy Hook under the direction of the ordnance board 174 rounds, the record of which is herewith appended.

This gun is now on exhibition at Philadelphia.

Record of firing for endurance with the 3.07 inch Moffatt B. L. experimental rifle No. 1.

Date.	Number of shots.	Charge.				Projectile.				Mean observed velocities of projectile at 70 feet from the muzzle of the gun, as recorded by Le Boulengé's chronograph.	Gas pressure per square inch of surface of bore, as taken with Rodman's internal-pressure gauge.
		Kind of powder.	Cartridge.								
			Weight.	Height.	Diameter.	Kind.	Weight.	Length.	Diameter.		
			Lb. oz.	*Inches.*	*Inches.*	*Shell.*	*Lb. oz.*	*Inches.*	*Inches.*		
March 19; April 22	12	New mortar.	1 4	4.90	3.10	Boston	10 4	.....	.....	1,120	19,500
March 21; April 26; May 15, 19; September 1, 1874; May 28, 1875.	62	New mortar.	1 4	4.90	3.10	Butler	9 8 to 10 4	7.50	3.00	.....	23,651
October 28, 1875	1	New mortar.	1 0	4.00	3.10	....do	9 8	7.50	3.00	.....	.....
March 19; September 1, 1874	16	New mortar.	1 4	4.90	3.10	Krupp	9 8 to 10 4	6.50	3.00	1,119	18,200
March 19, 1874	2	New mortar.	1 4	4.90	3.10	Krupp case-shot	9 3	7.00	3.00	1,157	16,500
March 19, 1874	5	New mortar.	1 4	4.90	3.10	Expanding shell	10 4	.....	.....	1,111	18,800
October 29, 1873; January 13, 29, 30; February 10, 23, 1874	19	New mortar.	1 4	4.90	3.10	....do	9 8	.....	.....	1,193	20,026
October 29, 1873; January 13, 29; February 6, 10, 23, 1874	34	New mortar.	1 4	4.90	3.10	Lead-coated	9 8	6.94	2.91	1,139	19,500
October 28, 1875	1	New mortar.	1 0	4.00	3.10	....do	9 8	6.94	2.91	.....	.....
March 19, 1874	3	New mortar.	1 4	4.90	3.10	Flat-head shot	10 4	5.06	2.91	1,124	25,373
October 29, November 13, December 28, 1873; January 13, 30, 1874.	9	Old mortar.	1 4	4.90	3.10	Expanding shell	10 4	.....	.....	.....	27,666
October 29; November 13; December 28, 1873	10	Old mortar.	1 4	4.90	3.10	Lead-coated	9 8	6.94	2.91	.....	28,000
Total	174										

N. B.—No record for accuracy has as yet been made.

THE MANN 8".4 BREECH-LOADING RIFLE.

The board on heavy rifled ordnance, instituted under the act of June 6, 1872, for the selection of breech-loading and muzzle-loading ordnance for experiments and tests, recommended as follows:

"That inasmuch as the Ordnance Department is now in possession of an 8-inch breech-loading rifle, constructed according to the plan of H. F. Mann, of Pittsburgh, Pa., which has not, in the opinion of the board, been yet fired a sufficient number of times to fully test the value of the invention, * * * * * that such further trials as may be deemed necessary be made with the 8-inch gun referred to."

Accordingly, this gun was brought from Fort Monroe and prepared for further test. At the request of Mr. Mann, a new elevating-apparatus, of increased power, was applied, and the gun re-rifled and re-chambered, these changes being conducted under the personal direction of the inventor.

DESCRIPTION OF THE GUN.

The breech mechanism of this gun belongs to that system in which the breech-block remaining stationary, the body of the gun is made to revolve upon its trunnions the necessary degree to open and close the breech. It may be generally described as consisting of a breech-block attached by straps to the trunnions, with suitable devices for securing, first, the requisite closeness of contact with the breech for firing, and, second, for raising and lowering the breech of the gun to produce the necessary revolution about the trunnions.

To describe more particularly: Plate I, Fig. 1, A represents the cast-iron body of the gun, re-inforced about the breech with forged-rings, B, of wrought iron, shrunk on. The mass of metal C D, closing the bottom of the bore, consists of two pieces. The piece C, in front, constituting the breech-block proper, is loosely recessed upon the piece D in rear, and has a slight play back and forth, so as to admit of being pushed up in close contact with the breech when the gun is prepared for firing. The means of producing this movement in the block is furnished by the screw N, which, passing centrally through the fixed breech-piece D—the latter being bored and threaded to receive it—abuts against the rear face of the movable block. The outer extremity of the screw is fitted with a weighted lever or handle, L, (Fig. 2,) having "lost motion" checked by a lug, M, attached to the circumference of the screw shoulder.

Fig. 2, K K are the breech-straps, which are looped over the trunnions and, extending backward, are rabbeted upon and bolted to the fixed piece D. A second point of support for the breech-apparatus is supplied by the elevating device. This consists of two screws of the same pitch, one on either side of the breech, connected by a worm-gearing and operated by cranks which extend beyond the carriage. The rimbases are concentric with the trunnions, but project sufficiently beyond the surface of the gun to accommodate the loops of the breech-straps. In order to open or close the breech, the raising or lowering of the breech of the gun is effected by means of a crank and pinion, H I, centered upon the side of each breech-strap and working in a large-toothed segment, E, the crank-shaped axle G of which passes under the gun and through a slotted lug, F, and thus communicates the motion, produced by the crank, to the breech of the gun. The fixed breech-piece D and the straps are of wrought iron; the movable block C is of cast iron.

8.4 INCH MANN BREECH LOADING RIFLE.

Fig. I.

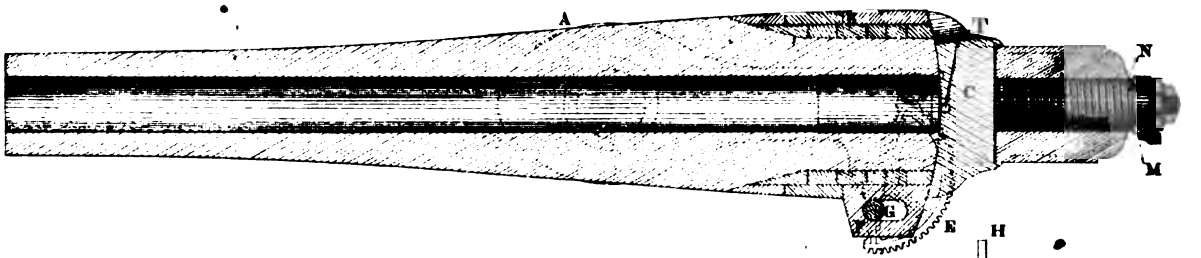
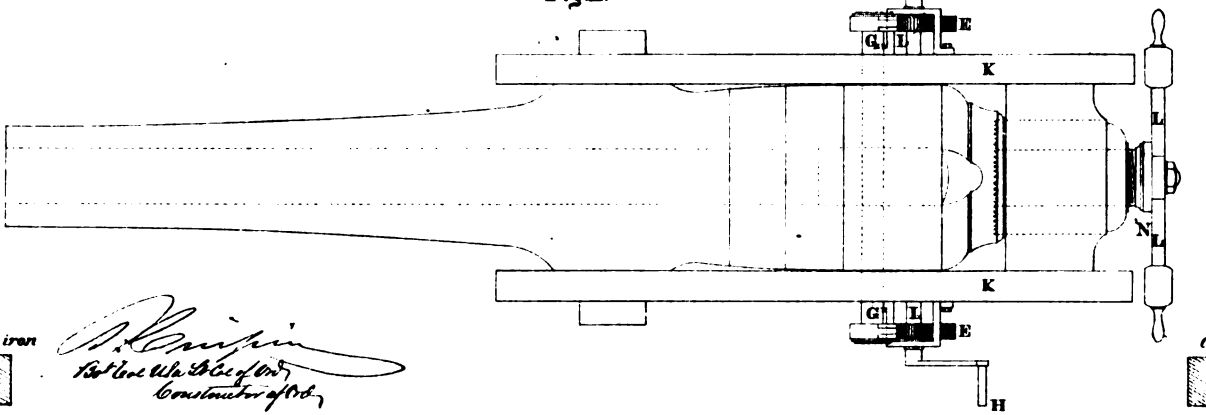


Fig. II.



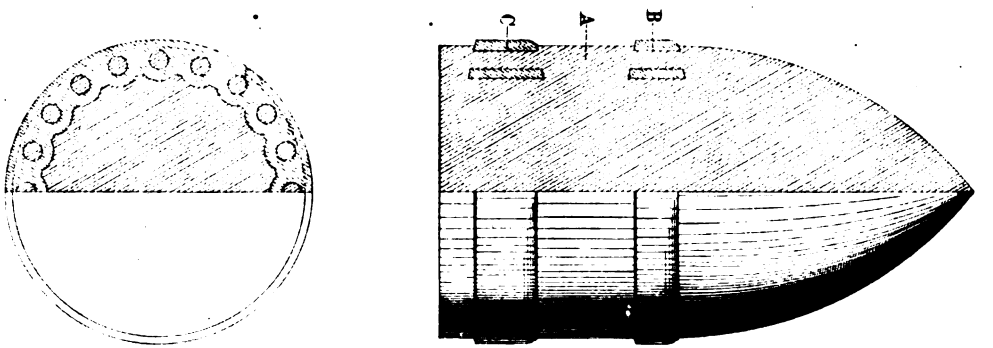
Wrought iron

Cast iron

Plate I.

Plate II.

PROJECTILE FOR 8.4 INCH MANN'S B.L. RIFLE.



169 lbs.

T. Crispin
Bvt Col Udn Lt Col of Ord
Constructor of Ord

RIFLING.

The gun is rifled with eleven lands and grooves, each of equal width, and of a uniform pitch of one turn in 60 feet.

Width of lands and grooves	1″.18524
Depth of grooves	0″.125

CHAMBERING.

The chamber is concentric with the bore, and of a diameter slightly greater than that of the bore between grooves; its capacity is sufficient to contain a charge of 30 pounds of powder and a shot of 170 pounds, the latter being inserted in the bore as far as its front band.

The top of each land is connected with the cylindrical surface of the chamber by a suitable ramp or bevel.

VENTING AND GAS-CHECK.

The gun is center-fire through a vent in the breech-block. This vent makes a turn at nearly right angles, so as to make its exit on top of the gun, as shown in the figure. Its interior opening is through a steel disk. The gas-check (designed by the inventor) used in this gun is shown in the figure; it is cup-shaped, and is pierced with a hole to admit the flame from the vent. It is necessary to remove this check before and replace it after loading. Gas-checks of this pattern, but of different alloys of copper, tin, zinc, and lead, were prepared with the view of determining the most suitable material.

PROJECTILE.

The projectile furnished by the inventor for this gun is shown in Plate II. It consists of a cast-iron body, having a front and rear band of soft metal—lead and antimony—encircling it. The iron body of the projectile allows the usual windage, but the lead bands exceed slightly the diameter of the bore, including grooves. The weight is from 150 to 170 pounds.

OPERATING THE GUN.

The gun is loaded as follows: The breech-screw is loosened, and the crank-handles turned until the gun, revolving on its trunnions, assumes a position in which the chamber is sufficiently exposed above the breech-block for the insertion of the charge. The gas-check is then removed, and the projectile inserted by sliding it along the trough T in the top of the breech-block, and pushing it forward until the front band stops against the rifling. The charge then follows, the gas-check is replaced, and the crank H reversed until the gun is restored in line with the breech-block; finally, the breech-screw is tightened by means of the two-handled lever L.

THE CARRIAGE

consists of a 10-inch carriage, widened to accommodate the increased length of the rimbases, with such other alterations as were required by the nature of the elevating-devices. The recoil-check was of the Parrott friction clamp-pattern.

ALTERATIONS.

The alterations in the gun were conducted at the West Point foundry under the supervision of the inventor. They consisted chiefly in enlarging the bore from 8″ to 8″.4, re-rifling and re-chambering, and applying the apparatus for elevating the gun, and for moving the breech in loading.

INSPECTION.

The gun was duly inspected after its final completion, and gave evidence of good finish.

PRINCIPAL DIMENSIONS.

Exterior diameter of gun at muzzle	15.00	inches.
Maximum diameter	28.50	"
Diameter of trunnions	10.00	"
Diameter of rimbases	17.00	"
Diameter of breech-screw, including threads	8.50	"
Diameter of breech-screw, excluding threads	7.00	"
Diameter of bore	8.40	"
Diameter of chamber	8.60	"
Radius of breech, (trunnions to breech)	51.25	"
Distance from trunnions to muzzle	92.75	"
Total length of gun	144.00	"
Length of breech-screw, including nut	28.00	"
Thickness of breech-straps	4.50	"
Depth of breech-straps at trunnions	25.00	"
Depth of breech-straps at breech-block	16.00	"
Depth of breech-straps at middle point	11.00	"
Length of chamber, including ramp	24.00	"
Total length of bore	144.00	"
Number of grooves	11	
Depth of grooves	0.125	inch.
Width of grooves and lands	1.18524	inches.
Pitch uniform; one turn in	60	feet.
Total length of gun over all	178.50	"
Total weight of gun	20,000	pounds.

EXPERIMENTS AND TESTS.

This gun had been fired some 50 rounds previous to alteration. After alteration it was fired two proof-rounds at the foundry before being sent to Sandy Hook, with charges of 20 pounds and 25 pounds, respectively, and shot of 170 pounds. At Sandy Hook it has been fired under the direction of the ordnance board eleven rounds, the record of which is appended.

The following are the characteristics of the powder used:

DuPont's hexagonal F. U. E. V., density 1.750.

DuPont's hexagonal F. U. E. V., granulation 72 to the pound.

DuPont's hexagonal F. P. G. H., density 1.785.

DuPont's hexagonal F. P. G. H., granulation 72 to the pound.

This gun is now on exhibition at Philadelphia, to be returned for additional tests at Sandy Hook.

Record of firing for endurance with an 8.4-inch Mann experimental breech-loading rifle No. 1, from April 17 to October 29, 1875, inclusive, at Cold Spring, N. Y., and Sandy Hook, N. J.

Date.	Number of shots.	Charge.				Projectile.				Mean observed velocities of the projectile at 110 feet from the muzzle of the gun, as recorded by Le Boulengé's chronograph.	Velocity at the muzzle.	Energy of projectile.		Gas-pressure per square inch of surface of bore, as taken with Rodman's internal pressure-gauge.	Recoil of upper carriage.
		Kind of powder: Du-Pont's hexagonal—	Cartridge.									Total at the muzzle.	Per inch of the shot's circumference.		
			Weight.	Height.	Diameter.	Kind.	Weight.	Length.	Diameter.			$\frac{WV^2}{2g}$	$\frac{WV^2}{2g2\pi R}$		
			Pounds.	*Inches.*	*Inches.*		*Pounds.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*	*Ft.-lbs.*	*Ft.-lbs.*	*Pounds.*	*Feet.*
April 17 to October 25	4	F. U. E. V	20	12.5	7.90	Mann	168	15	8.35	1,062	1,068	2,978,316	112,860	14,375	6.00
April 17 to October 25	3	....do	25	15.5	7.90	..do	168	15	8.35	1,252	1,260	4,145,425	157,087	17,166	6.37
October 26	2	....do	30	18.5	7.90	..do	168	15	8.35	1,406	1,416	5,235,471	198,392	25,500	7.22
October 26	2	F. P. G. H	30	7.9	7.90	..do	168	15	8.35						7.46
Total	11														

THE 3″.15 SUTCLIFFE BREECH-LOADING RIFLE FIELD-GUN.

The gun devised for trial in this instance was procured by converting a 3-inch service wrought-iron muzzle-loader to a breech-loader, on the Sutcliffe plan, and adding such other alterations as to rifling and chambering as the character of the piece demanded.

DESCRIPTION OF THE GUN.

The breech mechanism is essentially the same as that described for the 9-inch Sutcliffe gun, the slight points of difference resulting chiefly from the lighter caliber of the field-piece, and from the fact of its being a converted gun—not a new construction.

Referring to Plate II, Fig. 1, S represents the hollow steel breech-screw; B the movable breech-block, also of steel, attached to the screw by the pin *a*, and about which, as a pivot, the block is free to turn.

The pocket or slot P extends entirely through the side of the gun, owing to the slight diameter of the breech. A hood, which is firmly screwed to the exterior of the gun, covers the pocket and protects the breech-block. The screw is operated by a pair of handles, *h*, attached to the brass collar *d*, which is slipped over the base of the screw and affixed thereto by a set-screw. The collar may be readily detached.

The breech being closed, as in Fig. 1, a turn of the screw, three-fourths of a revolution to the left, lowers the block into the pocket and exposes the chamber, as shown in Fig. 2; a converse turn of the screw to the right raises the block from the pocket and carries it forward 0″.1, pressing it firmly against the gas-check and closing the breech. The front face of the breech-block is protected by the cup-shaped obdurator-plate of hardened steel. This plate is removable, and may be replaced should it become bruised or injured.

The gas-check is of the Broadwell pattern, single-lipped. The interior diameter of the breech-screw is sufficient to admit of the ready insertion of the cartridge and projectile.

RIFLING AND CHAMBERING.

The rifling consists of eleven lands and grooves each, of equal width, 0″.45, the grooves being 0″.05 deep with edges parallel; the side of each groove is parallel to a line passing through the center of the bore and the middle point of the groove. The pitch is uniform, and makes one turn in 11 feet. The chamber of the piece is a powder-chamber merely, the projectile occupying no part of it when the piece is loaded. Its diameter is that of the bore plus twice the depth of the rifling; therefore the bottom of each groove may be said to be a continuation of the surface of the chamber.

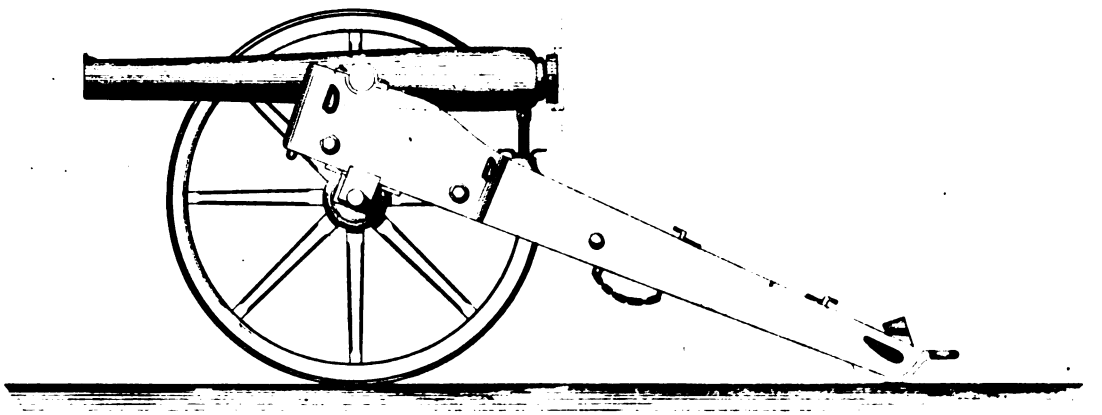
The cylindrical surface of the chamber is connected with the top of each land by a bevel 1 inch long, or having an inclination of one in twenty. The chamber is 5½ inches long, (practically, 5 inches when the projectile is inserted,) and accommodates a 1½ pound charge of powder. There is one vent in the normal position on top of the piece.

PROJECTILE.

The projectile adopted for this gun is shown on Plate III, Figs. 1 and 2. It differs from the Butler expansive projectile used with muzzle-loading guns simply by having the sabot flared outward from about the middle point to the outer edge of the upper or expansive lip. This increased diameter of the sabot affords the necessary "stop" in loading, and prevents the projectile from entering the bore any further than sufficient to provide the requisite powder-chamber behind it. The projec-

Plate I.

3.15 INCH SUTCLIFFE BREECH-LOADING FIELD-PIECE.



S. Crispin
Bot Col & Sta Lt Col of Ord
Constructor of Ord

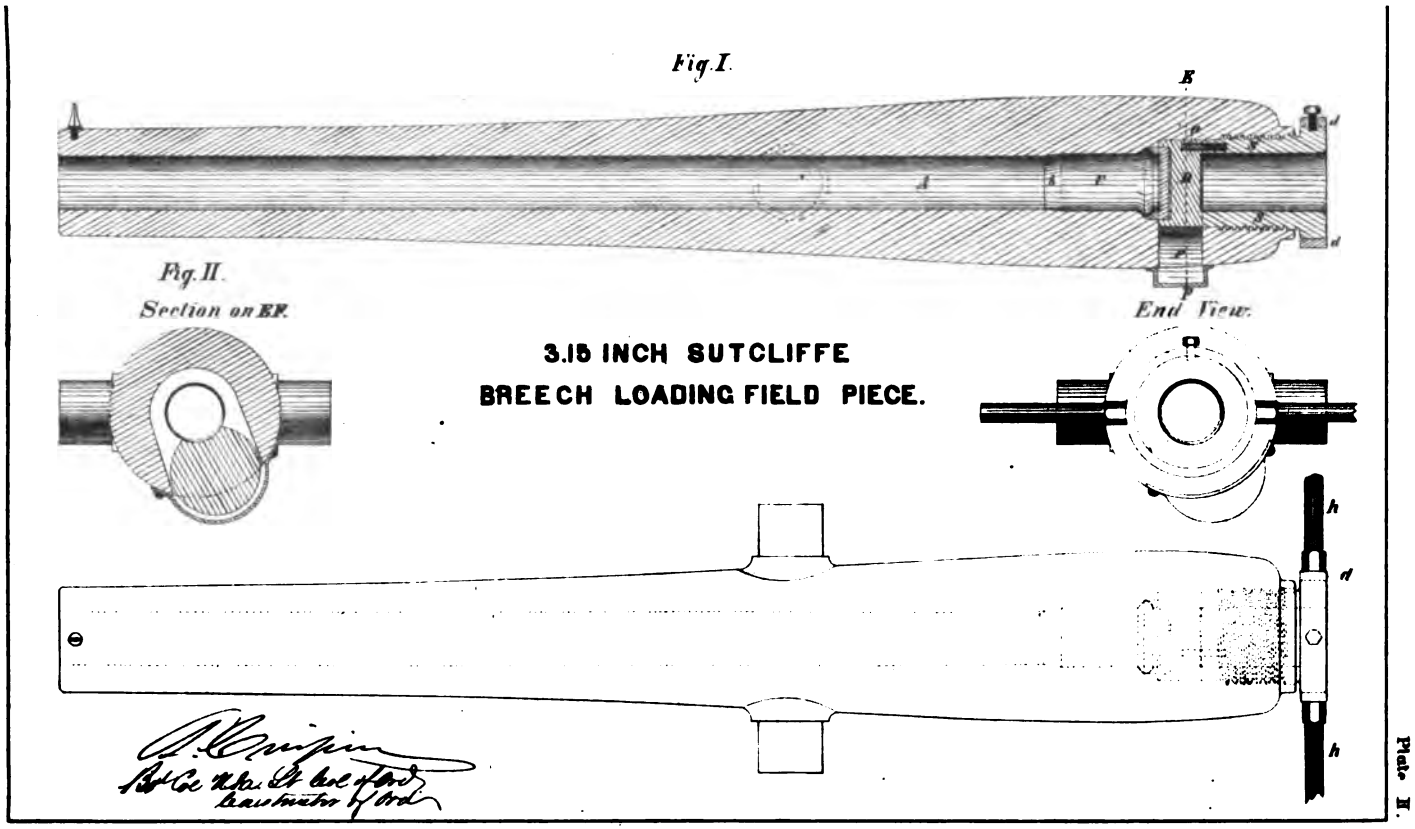
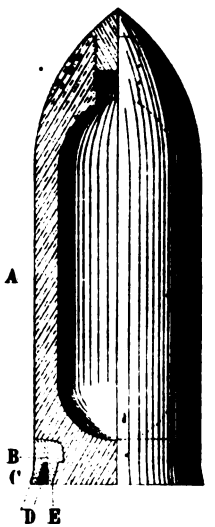


Fig. I.
E
Fig. II.
Section on EF.
End View.
3.15 INCH SUTCLIFFE
BREECH LOADING FIELD PIECE.
h
d
h

Plate II.

PROJECTILES FOR 3.15 INCH SUTCLIFFE'S B.L. FIELD PIECE.

Fig. 1.



10 lbs.

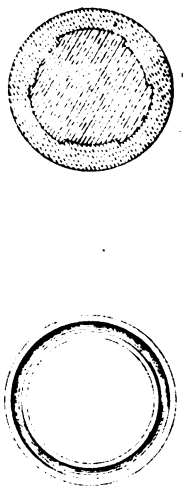
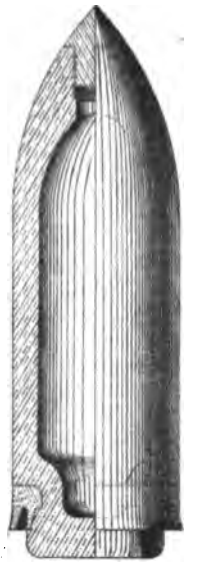


Fig. 2.



11 lbs.

A. Crispin
Bt Col Ute Lt Col of Ord
Contractor of Ord

tile (when loaded) rests in the rifled portion of the bore, and the flared sabot is jammed against the beveled junction of the chamber and rifling. When the gun is fired, the sabot is expanded into the rifling at the same time that it is compressed by the lands as the shot moves forward from position. Weight of projectile, 10 pounds.

CARRIAGE.

The gun being of the 3-inch wrought-iron model, it was already adapted to the service 6-pounder carriage, and no modification was necessary for its further adaptation after alteration. By increasing the height of the cheeks 1 inch, as great an elevation can be obtained as before alteration. On Plate I, the gun is shown mounted on its carriage.

FABRICATION OF THE GUN.

The breech-screw and breech-block were manufactured at the Midvale Steel Works, Philadelphia, from a good quality of steel, the screw being tempered in oil. The work of conversion was performed at the West Point foundry, under the immediate supervision of the inventor, and consisted chiefly in boring the gun through the breech, thereby removing the cascable, boring up the bore to a diameter of 3″.15, chambering, and re-rifling the bore as above described, and finally in adapting the breech to the Sutcliffe mechanism. The bottom of the chamber was recessed in the usual manner for the reception of the gas-check.

INSPECTION.

The finished gun showed evidence of good workmanship.

DIMENSIONS.

Length of rifled portion of bore	58.00 inches.
Length of beveled junction of bore and chamber	1.00 inch.
Length of chamber	5.5 inches.
Length of pocket, (in direction of bore)	2.65 "
Length of breech-screw, including shoulder	7.00 "
Total length of gun	73.00 "
Number of threads on breech-screw	10
Pitch of screw	0.4 inch.
Pitch of rifling, uniform; one turn in	132.00 inches.
Number of grooves	11
Depth of grooves	0.05 inch.
Width of lands and grooves	0.45 "
Weight of gun complete	800 pounds.
Weight of gun and carriage	1,700 "
Diameter of bore across lands	3.15 inches.
Diameter of bore through grooves	3.25 "
Diameter of chamber	3.25 "
Diameter of breech-block	5.00 "
Diameter of breech-screw across threads	5.50 "
Diameter of breech-screw between threads	5.00 "
Diameter of interior of breech-screw	3.40 "
Diameter of gas-check and chamber, (greatest)	3.25 "
Diameter of breech-screw collar	6.79 "
Diameter of breech-block pin	0.5 "

EXPERIMENTS AND TESTS.

Appended is a record of 53 rounds, fired partly at Governor's Isl: under direction of Capt. J. G. Butler, Ordnance Department, and pa at Sandy Hook, under direction of the ordnance board. This gu now on exhibition at Philadelphia, and awaits additional test.

Record of firing, for endurance, with a 3.15-inch Sutcliffe breech-loading rifle.

Date.	Number of shots.	Charge.				Projectile.				Mean observed velocities of the projectile at 70 feet from the
		Kind of powder.	Cartridge.			Kind.	Weight.	Height.	Diameter.	
			Weight.	Height.	Diameter.					
			Lbs. Oz.	*Inches.*	*Inches.*		*Lbs. Oz.*	*Inches.*	*Inches.*	F
August 4, September 5, and December 23, 1874; October 26, 1875...	30	Mortar-powder.	1 4	4.90	3.10	Butler shell	10 00	8.13	3.13	
September 5, 1874...	5		1 4	4.90	3.10	....do	10 13	8.13	3.13	
August 4.....	18		1 4	4.90	3.10	Butler shot	10 14	5.43	3.13	
	53									

NOTE.—No tests for accuracy have yet been made. The breech mechanism, as far as tested, (53 ro gives satisfactory results.

THE THOMPSON 12-INCH BREECH-LOADING RIFLE.

Under the act of June 6, 1872, the board on heavy rifled ordn selected as one of the models for experiments and tests a gun of 8- caliber on the Thompson system, to be constructed of cast iron wi steel lining. Subsequently a caliber of 12 inches was decided upo the department.

Under date of June 27, 1873, instructions were received from the partment to contract with the company representing the inventor, Thompson, for the fabrication of the gun, the work to be carrie under the general supervision of this agency, and under the immed supervision of the inventor or parties representing him. Such cont was made on the 28th of June, 1873, and the order to commence w on the gun issued from this office on the same date.

DESCRIPTION OF THE GUN.

Plate I, Figs. 1 and 2. The gun proper consists of a cast-iron b A, of the usual Rodman model, embracing, by light shrinkage, a tube, B, of uniform thickness, which extends throughout the bore, is secured in position by a screw-thread at the breech-end. The end of the tube is smoothly-faced, and abuts against the breech-bl The breech-block C works in a slot in the cast-iron casing at r angles to the bore; it is circular in cross-section, and is rolled later

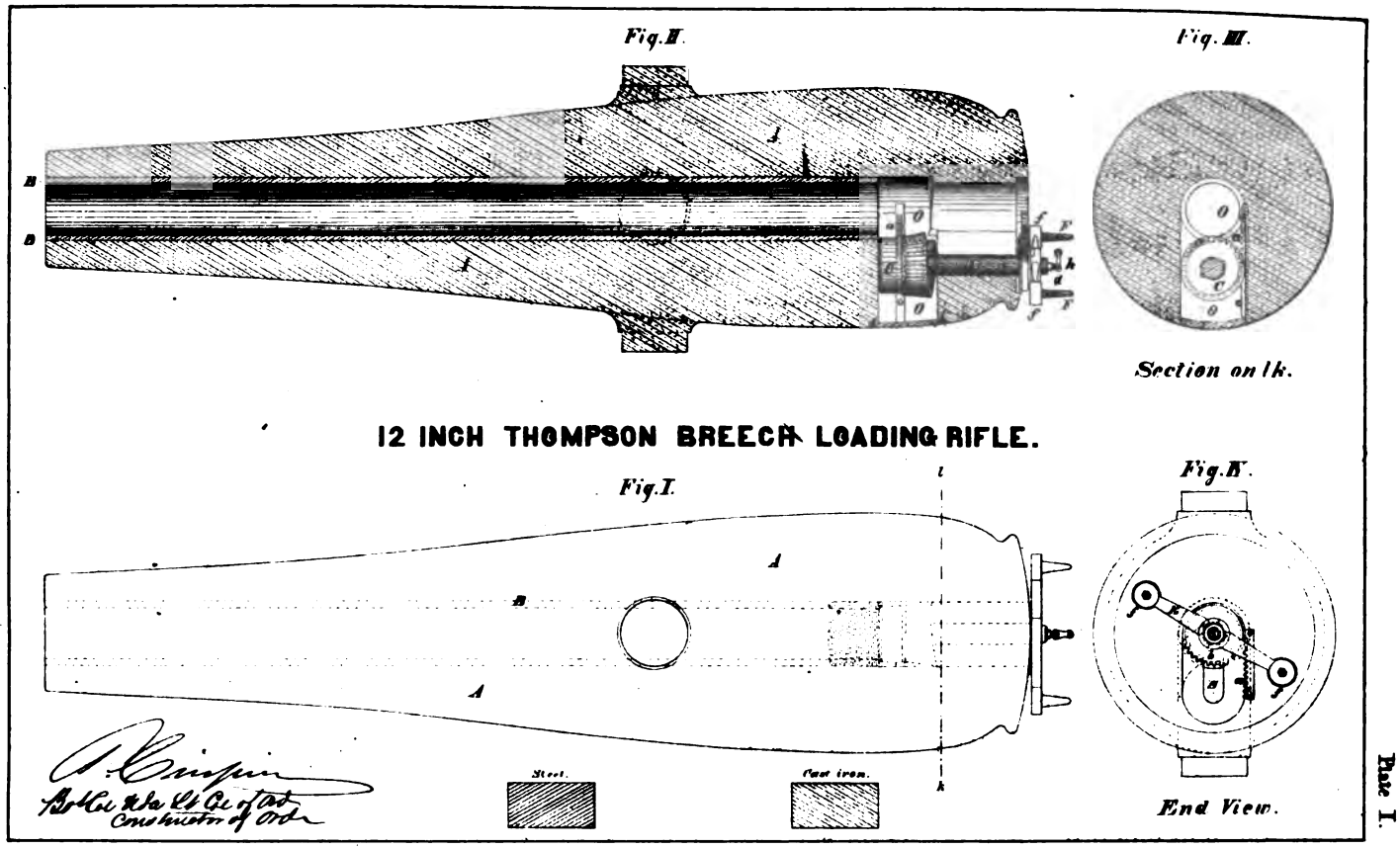
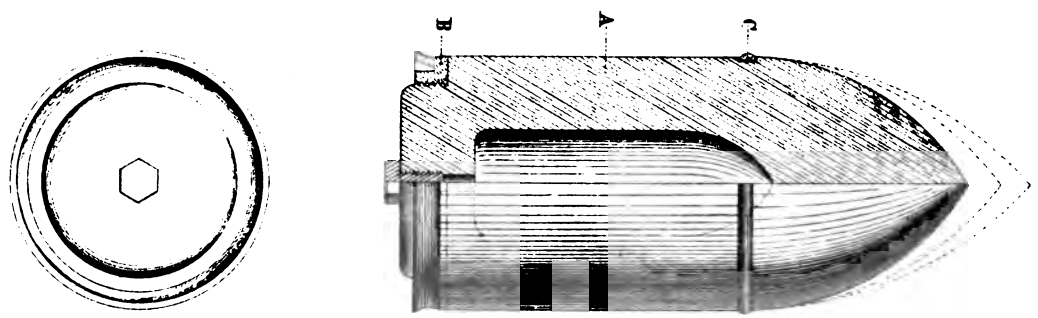


Fig. II.
Fig. III.
Section on lk.
12 INCH THOMPSON BREECH LOADING RIFLE.
Fig. I.
Fig. IV.
Steel.
Cast iron.
End View.
Constructor of Ord

Plate II

PROJECTILE FOR 12 INCH THOMPSON'S B.L. RIFLE.



595 lbs.

A. Crispin
Bot Col Mdn Lt Col of Ord
Constructor of Ord

15 INCH CARRIAGE ALTERED FOR THE 12 INCH THOMPSON RIFLE.

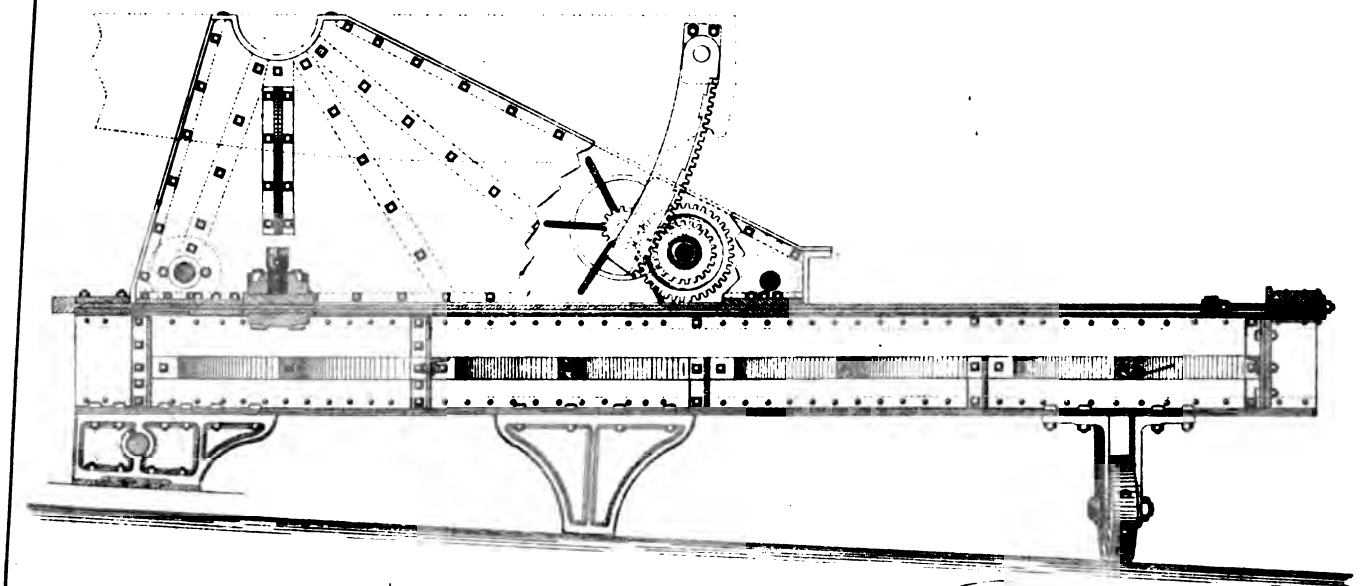
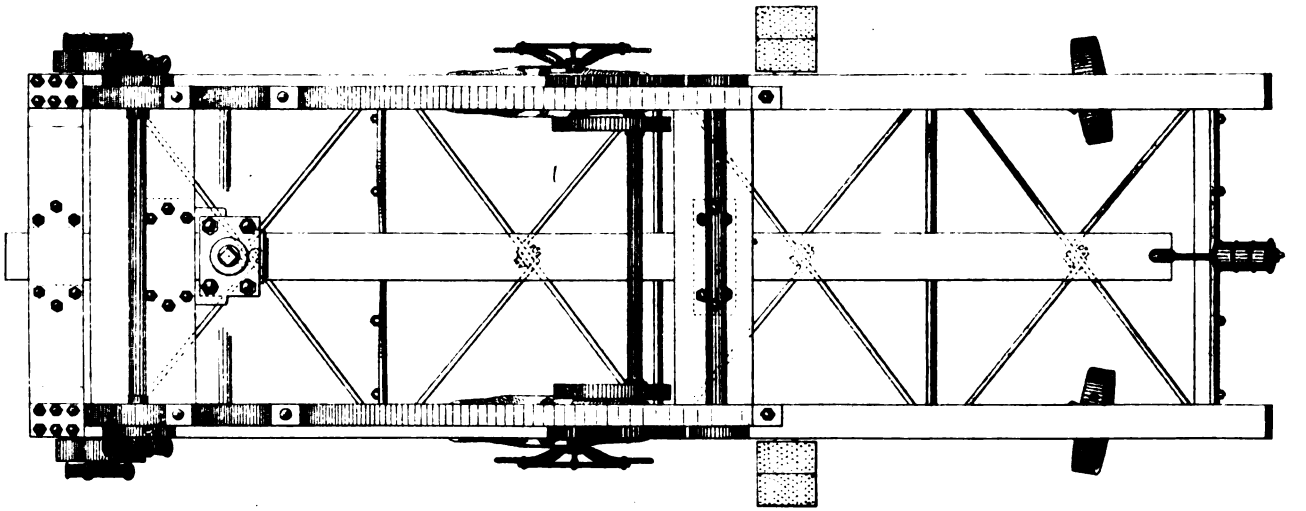


Plate II

Plate IV.

15 INCH CARRIAGE ALTERED FOR THE 12 INCH THOMPSON RIFLE.



A. Crispin
Bottled Usa Lt Col of Ord
Constructor of Ord.

to and fro into position for loading and for firing, a portion of its cylindrical surface being cut into cogs which fit into a toothed rack, *a*, Fig. 3, laid horizontally upon the floor of the slot. Power is applied by means of a lever, E, Fig. 4, which is attached to a shaft or spindle, D, Fig. 2, secured to the center of the breeh-block and extending outward through the breech of the gun in the direction of the axis of the bore. As the breech-block is rolled back and forth the spindle also traverses the face of the breech, a slot being cut for this purpose large enough to allow the requisite space. A toothed disk, *a*, Fig. 4, attached near the outer end of the spindle and working in a rack below, serves to secure steadiness of motion. The back of the breech-block is faced with a cam, which, as the breech is closed, comes in contact with a corresponding cam on the rear face of the slot, by which means the block is forced forward until its beveled front face (see Plate) is in close contact with the correspondingly-faced end of the tube, and the breech effectually closed. When closed, the breech-block is supported in rear throughout so much of its circumference as is not intersected by the slot in which the spindle moves. There is no means provided at present for locking the breech in position after it has been closed. The breech-block, the spindle, and the cam upon the face of the slot are of steel.

RIFLING.

The rifling of this gun is only provisional, it being proposed that, ultimately, it shall have twenty-one grooves and lands, each of equal width. At present every third groove only is cut, so there are but seven grooves.

	Inches.
Width of grooves	0.9
Width of lands	4.5
Depth of grooves	0.1

Twist, one turn in 70 feet.

CHAMBERING AND VENTING.

The chamber at present employed is of two diameters; that of the larger part, or powder-chamber, being equal to the diameter of the bore through the grooves; that of the smaller part, or shot-chamber, being equal to the diameter of the bore across lands, plus the depth of one groove. The length of the powder-chamber is 17.25 inches, commencing at the breech-block; the length of the shot-chamber is 14.72 inches, estimating from the powder-chamber to the rifled portion of the bore. The chambers are connected by the appropriate ramp; the junction of the bore and shot-chamber has an inclination of 1 in 8.

There is no provision made for a gas-check or for a vent proper, as it was the intention of the inventor to use metallic cartridge-cases, center-primed, discharged by a firing-pin passing through the centers of the breech-block and spindle, and cocked and discharged by a suitable device.

The breech-end of the tube is slightly beveled on the interior, to receive the flange of the cartridge-case. The rifling and chambering of this gun were adopted at the request of Mr. Thompson's engineer in charge, who wished to make some practical observations as to the power required to rotate the projectile. It is contemplated in the proposed modification of the chamber that it shall have a capacity for 120 pounds of powder.

PROJECTILE.

The projectile at present made for this gun is the Butler breech-loading projectile with double bearings. The front bearing consists of a light ring of soft brass applied to the forward end of the projectile, and of a diameter only 0″.05 in excess of the bore, and is not intended to aid materially in conveying rotation. The rear bearing or rotating device consists of a double-lipped ring, the outer lip of which is flared so as to exceed the diameter of the shot-chamber. This projectile is illustrated on Plate II. The front bearing-band C is seen to be secured to the projectile by an annular undercut, into which it is "crowded" cold. The sabot B in the rear is attached by a screw-thread. The distance from the apex of the front band to the flare of the sabot is such that when the projectile is pushed forward in the chamber, the front and rear bearings shall meet the front and rear ramps of the chamber respectively, and thus cause the projectile to be accurately centered in the operation of loading. Weight of projectile, 600 pounds. It is also intended to experiment with projectiles having grooved copper lands, front and rear, as now used in France and Germany.

FABRICATION OF THE GUN.

The steel tube and breech-block were manufactured by the Bochum Steel Company, Bochum, Prussia, and were guaranteed to be fully equal in quality to specimens previously furnished by them to the Ordnance Department.

Specimens extracted from the muzzle-end of the tube were tested with the following results:

Specimen.	Density.	Area of section broken.	Tenacity per square inch.	Where tested.
			Pounds.	
No. 1	7.8486	0.38154	90.172	Boston.
No. 2	7.8498	0.38154	85.212	Agency, New York.

The iron casing was cast and finished at the South Boston foundry, at which place, also, the steel tube was rifled and inserted and the breech-mechanism applied.

The gun-casing was cast on the Rodman plan, and cooled from the interior by a current of cold water. Owing, however, to the bulk of the casting and the weight of metal employed—which considerably exceeded any previous demand made upon the resources of the foundry—it was necessary, in the first instance, to strengthen the furnaces, enlarge the gun-pit, provide new flasks for the molds, and lengthen out the lathes.

THE FURNACES

There are three furnaces available at this foundry for purposes of cannon-founding. They are of the usual form of reverberatory air-furnaces, and have a capacity of about 28 tons of metal each.

IRON.

The iron employed was Richmond pig, remelted and graded, as follows:

	Pounds.
No. 1, soft	12,800
No. 2, under medium	29,874
No. 2, above medium	44,947
No. 3, hard	44,947
Remelted, hard	27,615
Total	160,183

This charge was distributed between three furnaces, in such proportions as to be melted in each in about the same time.

GUN-PIT AND FLASK.

The gun-pit is about 11 feet in diameter and 20 feet in depth; its bottom is covered with a cast-iron plate 2½ inches thick, and the walls are of boiler-iron, bricked up on the inside with two courses. The pit was in good condition, and was heated by fire previous to cooling. The flask in which the gun was cast was in sections, six in number, opening longitudinally, and having a circular cross-section, excepting a slight bulge at one point where the side-runner passed down. The mold of sand was formed within the flask in the usual manner.

CASTING.

The furnaces were fired at 5.30 a. m. February 6, and the metal was down at 12.15 p. m.; it remained in fusion four hours, after which it was conducted in the usual manner, by troughs, to the gun-mold. The operation of casting occupied 21 minutes.

COOLING.

Water was allowed to circulate through the core-barrel at the rate of 48 gallons per minute, entering at 31° and leaving in 45 minutes at 68°. One hour after casting fires were started in the pit and kept burning for 40 hours, after which they were allowed to die out. At the expiration of 24 hours the core-barrel was removed and water injected into the gun at the rate of 24 gallons per minute, entering at 38° and leaving after 15 minutes at 60°. It required 120 hours to entirely cool the gun, after which it was removed from the pit and placed in the lathe.

Full details of the casting and cooling are given in the tabulated foundry-history of the gun, appended. (Table 1.)

TURNING, BORING, AND RIFLING.

The gun was now turned to its prescribed exterior dimensions and bored for the reception of the steel tube. Careful star-gaugings showed the bore to be without eccentricity, smooth, and flawless, varying in diameter, but quite uniformly, from 15″.509 at the breech to 15″.505 at the muzzle. While in the lathe a ring 3″.68 in thickness was cut from next the face of the muzzle, from which, after testing for initial tension, specimens were cut for ascertaining the density and tenacity. These specimens were tested with the following results:

Initial tension, 18,500 pounds, or in a ratio of 0.533 to the absolute strength of the metal on the exterior.

Specimens, where taken.	Density.	Tensile strength.	
		Area of section broken.	Tenacity per square inch.
		Inches.	*Pounds.*
No. 1, outside	7.2729	1.1122	34,529
No. 2, 2″ from middle	7.2777	1.1178	30,746
No. 3, middle	7.2900	1.1122	29,943
No. 4, middle	7.2789	1.1141	29,710
No. 5, middle	7.2746	1.1178	29,522
No. 6, 2″ within middle	7.2970	1.1178	33,636
No. 7, inside	7.2900	1.1159	33,866
Mean	7.2858	.....	31,707

The steel tube which, in the mean time, had been finished, bored, and rifled, was now turned very smoothly throughout its exterior and to a diameter of 15″.507, after which the screw-thread was cut upon its lower end to correspond to the female thread already cut in the breech of the casing, except that as it was contemplated inserting the tube by the application of heat to the cast-iron casing, a play of 0″.06 was allowed between the threads for longitudinal expansion. By reference to Table 2, showing relative diameters of tube and cast-iron casing, it will be seen that for a distance of 35 inches from the seat of the thread at the breech, the tube is 0″.002 smaller than the bore of the casing; that this minute play becomes gradually less toward the muzzle until it disappears at a point 50 inches from the breech-screw, at which point, and for a distance of 17 inches, the tube and bore are of the same diameter. Throughout the remainder of the bore the diameter gradually contracts from 0″.002 to 0″.003, the diameter of the tube remaining constant. As the cast-iron casing would contract in cooling beyond its original diameter, it was thought that the above differences in diameter were within safe limits for securing a close contact between tube and gun.

INSERTING THE TUBE.

The tube being finished, the gun was removed from the lathe and placed vertically, breech down, in the pit in which it had been cast, and securely braced. Since any inequality in the temperature on opposite sides of the heated gun would result in a deflection of the axis of the bore, the chief obstacle opposed to the successful insertion of the tube lay in the difficulty of equally heating the metal throughout any cross-section of the gun; a difficulty that was increased in the neighborhood of the breech, owing to the preponderance of metal on the side opposite to the breech-slot. The arrangements made by the Foundry Company, however, preliminary to the insertion of the tube, were devised with a view to meet the difficulties involved in the proposed operation. The pit was surrounded by four furnaces placed at equal intervals around the wall, and capable of holding about 400 pounds of coal each; two flues were provided for furnishing air to these furnaces, one on either side of the pit, with branches at the bottom so that the air could be delivered directly under the furnace-grates, while near the top of the pit an opening was made

and connected with a chimney, and a damper inserted in the opening, by means of which the draught could be regulated. To obviate any difficulty in extracting the tube should it bind in any position short of "home," on account of the curvature of the bore of the casing, or the expansion by the heat of the tube itself, a water-cap was fitted to the muzzle-end of the tube, with inlet and outlet pipes, and a suitable arrangement of hose, so that a flow of cold water could at any time be injected into the tube, or kept circulating through it, and thus deprive the tube of much of the heat absorbed from the casing. This arrangement answered its purpose satisfactorily.

EXTRACT FROM A REPORT MADE AT THE SOUTH BOSTON FOUNDRY ON THE INSERTION OF THE TUBE.

"On Monday, March 1, at 8.30 a. m., the fires in three furnaces were lighted, but the fourth failed to ignite till about 3 p. m. At 6 p. m. they were all burning brightly.

"On Tuesday, March 2, at noon, the temperature of the pit about 5 feet down was 660° and 670°, and the temperature of the bore of the gun near the thread, 510° and 520°. The enlargement of the bore of the gun was .051 inch.

"In the afternoon an attempt was made to insert the tube. During the insertion the tube was kept cool by a current of water. It was lowered slowly on the crane and went down within 10 inches of the thread, when it stopped, showing it bound, and was withdrawn without difficulty. The appearance of the tube after it was withdrawn indicated that the bore of the gun was curved, and it was found that the side of the gun which was solid had expanded more than that in which the slot had been cut.

"On Wednesday, March 3, the fires were changed so as to bring the preponderance of heat on the concave side of the gun.

"On March 4, in the a. m., the temperature of the pit was 560°; temperature of the bore was 520°. In the p. m. the temperature of the pit was 510°; temperature of the bore of the gun 560°. The enlargement of the bore was .049 inch.

"At 3 o'clock another trial of the tube was made. It went down to the thread without binding, showing that the bore was straight. The screw entered and the tube was turned so that it was within 6 inches of the bottom, when it stuck and was withdrawn with some difficulty. The bore was measured about half an hour after the tube was withdrawn, and showed an enlargement of .016 inch. The gun was then allowed to cool so that the thread could be examined. It was found that, owing to the screw not entering properly and over-riding, or from the presence of dirt, or from both these causes combined, the screw and nut did not work normally. No injury was done to the tube or gun beyond a slight abrasion, and they were restored by a little filing. The diameter of the bore of the gun was now about 15.502 inches near the thread, and 15.504 inches near the muzzle, but a slight allowance should be made in these measurements, as they were taken with difficulty and might not be reliable.

"On Wednesday, March 10, everything being ready, the fires were relighted at 11 a. m. and again one missed, which finally ignited at about 4 p. m.

"On Saturday, March 13, the temperature of the pit was 680°; temperature of the gun was 660°. The enlargement at the muzzle was .055 inch.

"In the afternoon an attempt was made to insert the tube, and it was lowered about 130 inches in the bore, when it bound, and was again withdrawn. It was found that the gun was curved the same as before. The fires on the concave side of the gun were then forced and those on the convex side were banked, and on Monday, the 15th, another attempt was made to insert the tube. The temperature of the pit was now 570°, and that of the bore of the gun 583°. The enlargement of the bore was not measured, but was supposed to be about .05 inch, as this would be due to the degree of heat as found in previous experience. The tube was lowered slowly and went down easily to the thread, when the screw entered, and the tube was then turned gradually and moved without difficulty till it brought up against the shoulder, in its place, and the operation thus successfully completed. The operation lasted about twenty minutes, and during this time the temperature of the water rose to 50°, a gain of 8°. In half an hour after the tube had been inserted the temperature of the water had risen to 99°. More water was then turned on till the temperature had lowered to 60°, and held there for 30 minutes. At 12 m. the temperature of the water was 59°; at 1 p. m., 57°; at 2 p. m., 54°; at 3 p. m., 52°; at 4 p. m., 51°; at 5 p. m., 50°; at 6 p. m., 49°. The gun was now contracting on the tube, and had shortened 2 inches since the tube was inserted. The fires were all banked so that the gun might cool gradually. At 6 p. m. the water was turned off till the temperature had risen to 59°. On the morning of the 16th the covers were taken off the pit, and the furnaces were hoisted out. The temperature of the water on the 16th was as follows: At 8 a. m., 49°; at 11 a. m., 48°; at 12 m., 47°; at 2 p. m., 44°; at 4 p. m., 44°; at 5 p. m., 43°. On the morning of the 17th the water was down to the entering temperature, and it was shut off and the gun hoisted out. It was found by measurement that the gun, when the tube was inserted, had lengthened ⅜ inch in the length of the tube."

After its removal from the pit the gun was again placed in the lathe, and work resumed upon the breech-mechanism and housing.

INSPECTION.

The gun was completed in excellent workmanship, and was carefully inspected.

PRINCIPAL DIMENSIONS.

Exterior diameter of the gun at muzzle	27	inches.
Exterior diameter of the gun 25 inches from muzzle	29.2	inches.
Exterior diameter of the gun 45 inches from muzzle	31.6	inches.
Exterior diameter of the gun 65 inches from muzzle	34.6	inches.
Exterior diameter of the gun 85 inches from muzzle	38.2	inches.
Exterior diameter of the gun 105 inches from muzzle	42.6	inches.
Exterior diameter of the gun 125 inches from muzzle	47.6	inches.
Exterior diameter of the gun at breech	47	inches.
Exterior diameter of the gun at neck	43	inches.
Maximum diameter 41 inches from breech	56	inches.
Diameter of trunnions	15	inches.
Diameter of rim-bases	17	inches.
Diameter of exterior of steel tube	15.5	inches.
Diameter of breech-block 13, 10 and	15	inches.
Diameter of powder-chamber	12.30	inches.
Diameter of shot-chamber	12.155	inches.
Diameter of bore	12	inches.

h of powder-chamber	17.25	inches.
ı of first ramp	0.33	inch.
ı of shot-chamber	14.72	inches.
ı of second ramp	0.35	inch.
ı of rifled portion of bore exclusive of shot-cham-	159.35	inches.
ı of bore, including chambers	192	inches.
ıess of breech-block in direction of bore	12.4	inches.
of breech-block slot in direction of bore	12.5	inches.
ı of breech-block slot across bore	33	inches.
ter of breech-block spindle	5	inches.
ı of breech-block spindle	29.3	inches.
ı of trunnions	4.5	inches.
ce between rimbases	56.1	inches.
ıess of breech from face to breech-block	23.4	inches.
ter of loading chamber through breech	12.5	inches.
ength of gun	226.32	inches.
ɜr of grooves	7	
of grooves	0.1	inch.
of grooves	0.9	inch.
of lands	4.5	inches.

ɔf rifling, one turn in 70 feet.

THE CARRIAGE.

carriage provided for this gun is shown on Plates III and IV. It ıe general pattern of the 15-inch service-carriage, with such modi- ıs as the dimensions of the gun called for. A friction recoil-check tached, as shown in the figure.

EXPERIMENTS AND TESTS.

gun, upon completion, was sent to Sandy Hook, and fired two under the direction of the Ordnance Board. It was then sent to hibition at Philadelphia, to be returned (at the close of the Expo- for the contemplated additional experiments and tests. The firing of the two rounds is appended.

powder used was the same as that employed with the 8-inch rifles, ısity being 1.750 and the granulation 72 to the pound.

No. 1.—*History of the Thompson 12-inch breech-loader, built by South Boston Iron Company, (United States contract with Biddle Manufacturing Company.)*

Grade.	Charge of furnaces.			
	Furnace 1.	Furnace 2.	Furnace 3.	Total.
	4,267	4,267	4,267	12,801
	9,958	9,958	9,958	29,874
H	14,949	14,949	14,949	44,847
S	14,949	14,949	14,949	44,847
	9,205	9,205	9,205	27,615
	53,328	53,328	53,328	159,984

TABLE NO. 1.—*History of the Thompson 12-inch breech-loader, &c.*—Continued

	Coal consumed.			
	Furnace 1.	Furnace 2.	Furnace 3.	T
In melting	11,200	11,200	11,200	
In fusion	6,720	6,720	6,720	
	17,920	17,920	17,920	

Record.

	Februar
Furnaces fired at	5.30 a. r
Metal down at	12.15 p. r
Gun cast at	4.00 p. r
Time in fusion	3.45 p. r
Time occupied in casting	20 mi
Temperature of water entering core-barrel	30 de
Temperature of water leaving in 45 minutes at	68 de
Rate of water per minute	48 gal
Fire kindled in pit	5.00 p. r
	Februar
Fire went out	11.00 p. r
Fire in pit burned	30 ho
Water shut off	2.00 p. r
Core-barrel removed at	3.00 p. r
Water injected into gun	3.30 p. r
Rate of water per minute	24 gal
Temperature of water entering gun	38 de
Water left gun in 15 minutes at	160 de
Total time of cooling gun	116 ho

Cooling-table—core-barrel.

Hour.	Temp.	Hour.	Temp.	Hour.	Temp.	Hour.
	°		°		°	
5 p. m	68	12 p. m	60	8 a. m	58	2 p. m
6 p. m	68	2 a. m	59	10 a. m	58	
8 p. m	63	4 a. m	58	12 m	58	
10 p. m	61	6 a. m	58	1 p. m	57	

Cooling-table—gun.

Hour.	Temp.	Hour.	Temp.	Hour.	Temp.	Hour.	Temp.	Hour.	Temp.	Hour.	Temp.	Hour.	Temp.
	°		°		°		°		°		°		°
23	160	35	110	47	88	59	68	71	50	83	44	95	42
24	150	36	108	48	90	60	66	72	50	84	44	96	41
25	140	37	106	49	88	61	64	73	49	85	44	97	41
26	132	38	105	50	86	62	62	74	48	86	44	98	41
27	131	39	104	51	84	63	59	75	47	87	44	99	41
28	128	40	104	52	82	64	59	76	47	88	43	100	41
29	126	41	103	53	80	65	58	77	46	89	43	101	41
30	123	42	101	54	78	66	57	78	46	90	43	102	41
31	120	43	99	55	76	67	54	79	46	91	43	103	40
32	117	44	96	56	74	68	51	80	45	92	42	104	40
33	114	45	94	57	72	69	50	81	44	93	42	105	40
34	112	46	92	58	70	70	50	82	44	94	42	106	40

Initial tension.

Exterior diameter of ring.	Interior diameter of ring.	Thickness of ring.	Thickness of broken section.	Interior opening.	Exterior opening.	Circumference of exterior.	Extension per inch of exterior circumference.	Initial tension.	Ratio of initial tension to strength of exterior ring.
45″. 82	13″. 71	3″. 68	0″. 36 length, 13″. 6	.06	.155 or .1575	143.9481	.00107 or .00109	18400 18600	0.533

Mechanical tests made at United States Ordnance Agency, (iron and steel.)

Specimens.		Area of broken section in inches.	Density.	Tenacity, pounds per square inch.
				Pounds.
Cast iron	No. 1, outside	1.1122	7.2929	34,529
	No. 2, 2″ from middle	1.1178	7.2777	30,746
	No. 3, middle	1.1122	7.2900	29,943
	No. 4, middle	1.1141	7.2789	29,710
	No. 5, middle	1.1178	7.2746	29,522
	No. 6, 2″ within middle	1.1178	7.2970	33,636
	No. 7, inside	1.1159	7.2900	33,866
Steel tube	No. 1	0.38154	7.8486	90,172
	No. 2	0.38154	7.8498	85,212

TABLE No. 2.

Table showing relative dimensions of interior of cast-iron body of 12-inch Thompson rifle, and exterior of steel tube inserted therein.

Inches from muzzle.	Interior diameter of casing.	Exterior diameter of tube.	Difference or play.	Inches from muzzle.	Interior diameter of casing.	Exterior diameter of tube.	Difference or shrinkage.
	Inches.	*Inches.*	*Inches.*		*Inches.*	*Inches.*	
167	15.509	15.507	.002	97	15.506	15.507	.001
166	15.509	15.507	.002	96	15.506	15.507	.001
165	15.509	15.507	.002	95	15.506	15.507	.001
164	15.509	15.507	.002	94	15.506	15.507	.001
163	15.509	15.507	.002	93	15.506	15.507	.001
162	15.509	15.507	.002	92	15.506	15.507	.001
161	15.509	15.507	.002	91	15.506	15.507	.001
160	15.509	15.507	.002	90	15.506	15.507	.001
159	15.509	15.507	.002	89	15.506	15.507	.001
158	15.509	15.507	.002	88	15.506	15.507	.001
157	15.509	15.507	.002	87	15.506	15.507	.001
156	15.509	15.507	.002	86	15.506	15.507	.001
155	15.509	15.507	.002	85	15.506	15.507	.001
154	15.509	15.507	.002	84	15.506	15.507	.001
153	15.509	15.507	.002	83	15.506	15.507	.001
152	15.509	15.507	.002	82	15.506	15.507	.001
151	15.509	15.507	.002	81	15.506	15.507	.001
150	15.509	15.507	.002	80	15.506	15.507	.001

TABLE No. 2.

Table showing relative dimensions, &c.—Continued.

Inches from muzzle.	Interior diameter of casing.	Exterior diameter of tube.	Difference or play.	Inches from muzzle.	Interior diameter of casing.	Exterior diameter of tube.	Difference or shrinkage.
	Inches.	*Inches.*	*Inches.*		*Inches.*	*Inches.*	
149	15.509	15.507	.002	79	15.506	15.507	.
146	15.509	15.507	.002	78	15.506	15.507	.
145	15.509	15.507	.002	77	15.506	15.507	.
144	15.509	15.507	.002	76	15.506	15.507	.
143	15.509	15.507	.002	74	15.506	15.507	.
142	15.509	15.507	.002	72	15.506	15.507	.
141	15.509	15.507	.002	70	15.506	15.507	.
140	15.509	15.507	.002	68	15.505	15.507	.
139	15.509	15.507	.002	66	15.505	15.507	.
138	15.509	15.507	.002	64	15.505	15.507	.
137	15.509	15.507	.002	62	15.505	15.507	.
136	15.509	15.507	.002	60	15.505	15.507	.
135	15.509	15.507	.002	58	15.505	15.507	.
134	15.509	15.507	.002	56	15.505	15.507	.
133	15.509	15.507	.002	54	15.5045	15.507	.
132	15.509	15.507	.002	52	15.5045	15.507	.
131	15.508	15.507	.001	50	15.5045	15.507	.
130	15.508	15.507	.001	48	15.5045	15.507	.
129	15.508	15.507	.001	46	15.504	15.507	.
128	15.508	15.507	.001	44	15.504	15.507	.
127	15.508	15.507	.001	42	15.504	15.507	.
126	15.508	15.507	.001	40	15.504	15.507	.
125	15.508	15.507	.001	38	15.504	15.507	.
124	15.508	15.507	.001	36	15.504	15.507	.
123	15.508	15.507	.001	34	15.504	15.507	.
122	15.508	15.507	.001	32	15.504	15.507	.
121	15.508	15.507	.001	30	15.504	15.507	.
120	15.508	15.507	.001	28	15.504	15.507	.
119	15.508	15.507	.001	27	15.504	15.507	.
118	15.507	15.507	.000	24	15.504	15.507	.
117	15.507	15.507	.000	22	15.504	15.507	.
116	15.507	15.507	.000	20	15.504	15.507	.
115	15.507	15.507	.000	18	15.504	15.507	.
114	15.507	15.507	.000	16	15.505	15.507	.
113	15.507	15.507	.000	14	15.505	15.507	.
112	15.507	15.507	.000	12	15.505	15.507	.
111	15.507	15.507	.000	10	15.505	15.507	.
110	15.507	15.507	.000	8	15.505	15.507	.
109	15.507	15.507	.000	6	15.505	15.507	.
108	15.507	15.507	.000	4	15.505	15.507	.
107	15.507	15.507	.000	2	15.505	15.507	.
106	15.507	15.507	.000	0	15.505	15.507	.
105	15.507	15.507	.000				
104	15.507	15.507	.000				
103	15.507	15.507	.000				
102	15.507	15.507	.000				
101	15.507	15.507	.000				
100	15.507	15.507	.000				
99	15.507	15.507	.000				
98	15.507	15.507	.000				

Record of firings for endurance with the 12-inch Thompson breech-loading experimental rifle, No. 1, from March 20 to March 24, 1876.

Date.	Number of shots.	Charge.				Projectile.				Mean observed velocities of the projectile at 110 feet from the muzzle of the gun, as recorded by Le Boulengé's chronograph.	Velocities at muzzle.	Energy of projectile.		Gas-pressure per square inch of surface of bore, as taken with Rodman's internal pressure-gauge.	Recoil of upper carriage.
		Kind of powder—Du-Pont's hexagonal.	Cartridge.			Kind.	Weight.	Height.	Diameter.			Total at muzzle. $\frac{WV^2}{2g}$	Per inch of shot's circumference. $\frac{WV^2}{2g2\pi R}$		
			Weight.	Height.	Diameter.										
			Pounds.	*Inches.*	*Inches.*		*Pounds.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*	*Ft.-lbs.*	*Ft.-lbs.*	*Pounds.*	*Feet.*
March 20	1	F. U. E. V.	30	9.50	11.12	Butler	595	26	11.96	716	718	4,768,334	126,459	3,500	2.29
March 24	1	....do	40	12.00	11.12	...do	594	26	11.96	786	788	5,732,680	152,064	4,000	3.92

SUTCLIFFE 9-INCH BREECH-LOADING RIFLE.

The board on heavy rifled ordnance, instituted by the War Department by virtue of the act of Congress of June 6, 1872, among other recommendations, adopted one looking to the construction for experiments and tests of a cast-iron breech-loading rifle lined with a steel tube, the breech mechanism being after the plan invented by Mr. E. A. Sutcliffe, of New York City.

This recommendation was virtually approved by the action of the Department in authorizing, under date of January 3, 1873, the construction of a 9-inch cast-iron breech-loading gun lined with a steel tube, and embodying the breech-loading system of Mr. Sutcliffe, to be constructed under the supervision of the United States Ordnance Agency, and the inventor to be employed in the supervision of the construction of the breech-mechanism of the gun.

The caliber decided upon was 9 inches, but the dimensions given to the gun and lining-tube were such as to permit a boring up to a caliber of 10 inches. This provided, at a small additional outlay, for a test of the system, using one of our standard calibers, (10 inches;) contingent, of course, however, on satisfactory results being obtained in our contemplated experiments with the preliminary caliber of 9 inches.

The system not only provided for the test of the breech-mechanism, but also the test of a system of gun-construction based upon the lining of cast-iron guns with steel tubes, as proposed by the Ordnance Board of 1868.

The details of the gun-construction were, of course, as far as necessary, subordinate to the requirements of the breech system; and they were made so as to insure a surplus of strength, with respect to the latter, so as to have no giving away before the mechanism had been fairly tested.

DESCRIPTION OF THE GUN.

Plate I, Fig. 1, A is the cast-iron body of the gun, B is the steel tube, which, instead of the usual re-inforce of a jacket shrunk upon it, is simply made thicker or of greater exterior diameter throughout the lower half of its length. This tube is inserted from the rear and by means of hydraulic pressure. It is secured from being thrust forward under the action of firing by the shoulder S, formed by the beveled junction of the larger and smaller portions of the bore of the casing and by the steel muzzle-collar C, and is prevented from turning in the casing by the screw-pins I I, which are tapped through the casing and a short distance into the tube.

The breech-mechanism works in the cast-iron casing, and is independent of the steel tube. It consists of a hollow steel breech-screw, F, working in a corresponding female screw cut on the interior of the breech, and having attached to its front face, by means of a pin, *b*, a cylindrical steel breech-block D, of the same diameter as the screw between threads. The pin *b* is of steel, and is attached to the face and near the periphery of the breech-block, and about it, as a pivot, the block is free to turn. Only once during a revolution are the breech screw and block concentric. In this relative position they are inserted into the breech. Immediately in rear of the tube a slot or oblique pocket is cut in the casing for the reception of the block, when the breech is opened, and into which the block rolls as the breech-screw is reversed, thus exposing the powder-chamber. The interior diameter of the breech-screw is such as to admit of the free passage through it of the charge.

Fig. 1.

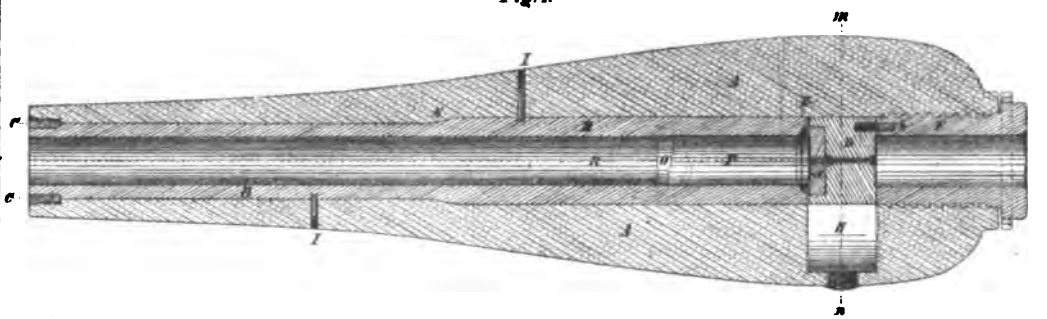
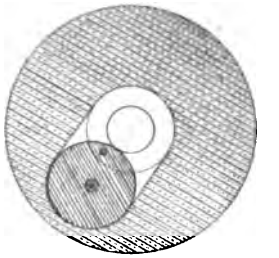


Fig. 2.



Section on m n.

9 INCH SUTCLIFFE BREECH-LOADING RIFLE.

Fig. 3.

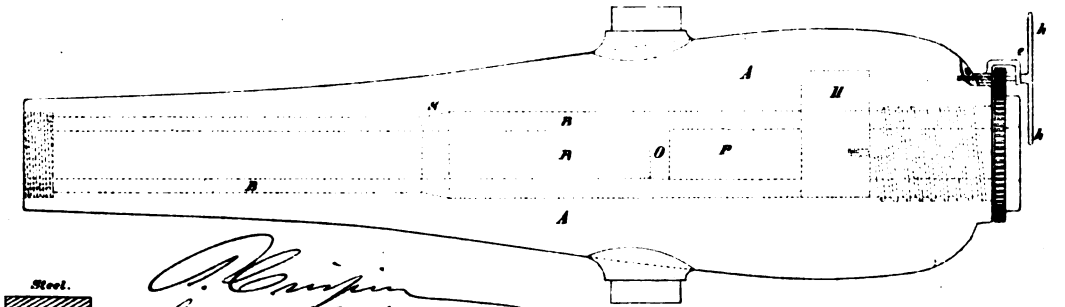
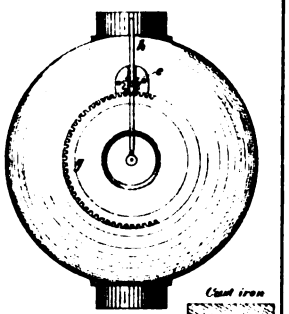


Fig. 4.



Steel.

Cast iron

Plate I.

SECTION THROUGH BREECH OF 9 INCH SUTCLIFFE B.L RIFLE.

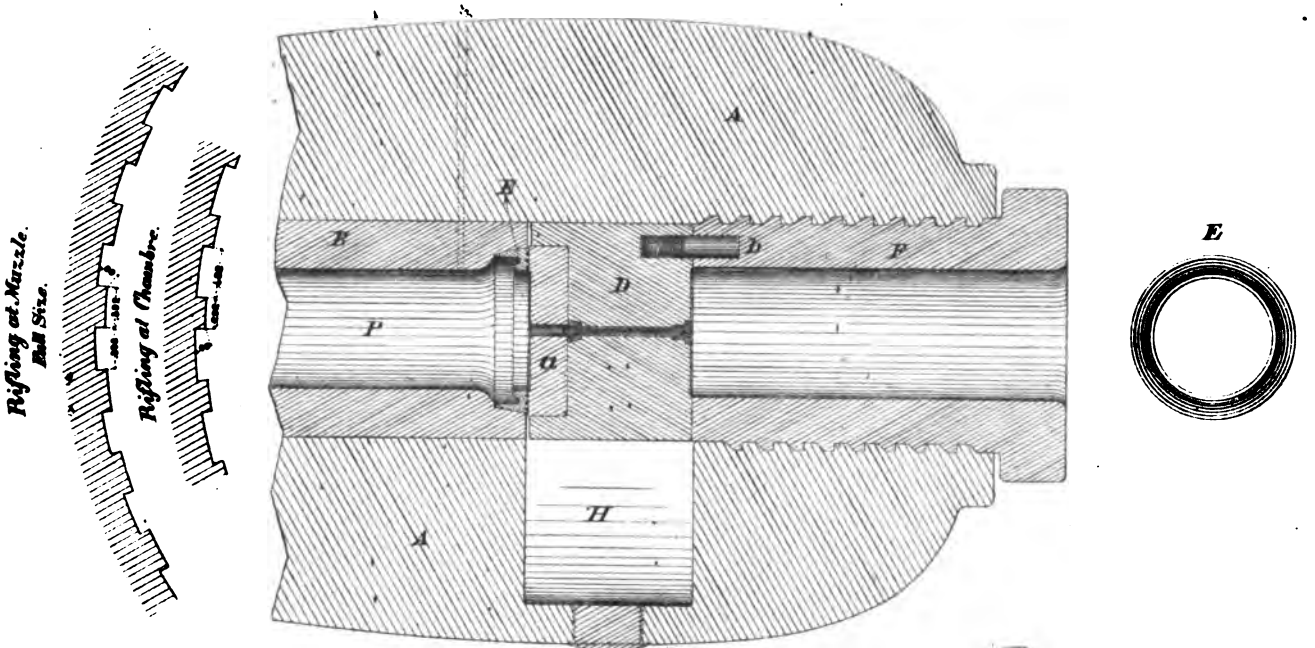
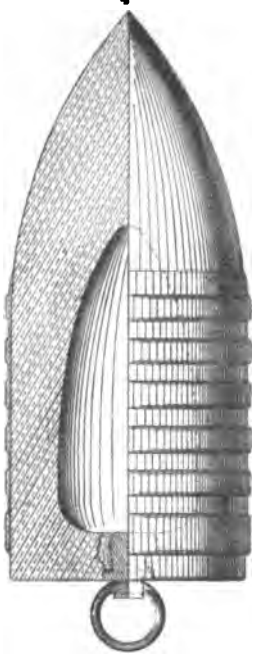


Plate I.

Plate II.

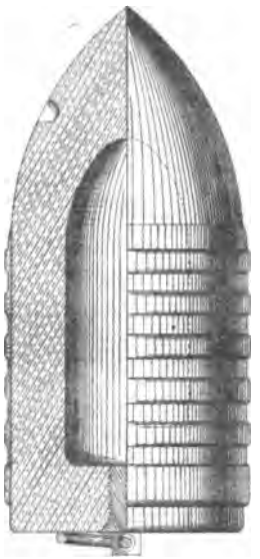
PROJECTILES FOR 9 INCH SUTCLIFFE'S B.L. RIFLE.

Fig. 1.



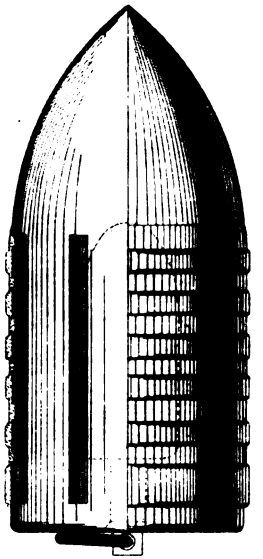
250 lbs.

Fig. 2.



234 lbs.

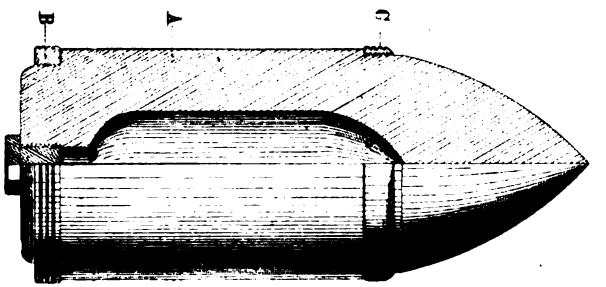
Fig. 3.



250 lbs.

[illegible]
Bot Col Wha L & Col of Ord
Constructor of Ord

PROJECTILE, PARKER, FOR 9 INCH SUTCLIFFE'S B. L. RIFLE.



250 lbs.

Cast iron

Copper.

Bot Col & Ins Lt Col of Ord
Constructor of Ord

The screw is operated by means of a pinion, *e*, (Fig. 3,) attached to the breech and working in a toothed segment, *g*, (Fig. 4,) on the shoulder of the breech-screw. This segment is attached by means of set-screws, and may be removed at pleasure. A handle, *h*, is attached to the pinion for the application of power. The front face of the breech-block is recessed for the reception of a hardened steel disk, called the obdurator plate, which abuts against the gas-check E, (Fig. 1,) a Broadwell ring, when the breech is closed. This plate is removable, and on being indented or bruised can be replaced. The gas-check projects 0″.5 beyond the face of the steel tube.

RIFLING.

The rifling consists of thirty-six lands and grooves each, of equal width at the muzzle, but the lands gradually narrow toward the breech, until their junction with the chamber, at which point they are 0″.1 less in width than at the muzzle. The twist is one turn in 60 calibers, or 45 feet. Full details of the rifling are given in Plate II.

CHAMBERING.

The axis of the chamber is eccentric with that of the bore, being placed 0″.05 above it, in order that the axis of the projectile (in the operation of loading) shall be coincident with the axis of the bore. The diameter of the chamber is 0″.3 larger than that of the bore, which, in connection with the eccentricity, gives to the surface O, (Plate I, Fig. 1,) uniting the bore and chamber, the form of a truncated cone. The chamber is of a size sufficient to contain the cylindrical body of a 250-pound projectile, and a maximum charge of 45 pounds of powder.

VENTING.

The gun has two vents, one in the normal position and the other through the center of the breech-block, either of which may be closed while the other is being used. The details of the venting are shown in Plates I and II.

The projectile for this gun is the ordinary lead-coated one, having a series of parallel ribs upon the surface of the coating. The coating may be attached either mechanically, by being cast on and held by under cuts in the surface of the projectile; or chemically, by a soldering process, both methods being used. The diameter of the projectile between ribs is 9 inches, the exact caliber of the gun, and the ribs project beyond this diameter 0″.2, being a little in excess of the depth of the rifling. The projectile, therefore, on being inserted in the gun, will slide forward until the front rib meets the rifling, where it will rest. Upon discharge, each of the lands plows a groove in the ribs, and this communicates the rotation due to the twist of the rifling. Plate III, Fig. 1, represents a projectile having a chilled-iron head, and the coating chemically attached. Figs. 2 and 3 represent projectiles of our own manufacture, and the two methods of attaching the lead coating. Weight of coated shot 250 pounds.

On Plate IV is shown an experimental projectile for the 9-inch Sutcliffe gun, made upon plans presented by Major F. H. Parker, Ordnance Department. It consists of a cast-iron body, A, banded with two rings, B and C, of soft copper, one at the base and the other at the front of the cylindrical portion of the body. Rotation is communicated by means of the rear band, the diameter of which is 9″.18, equal to that

of the bore between grooves, while the front band is designed to centre the projectile, its diameter being equal to that of the bore across lands. Both bands are attached by a screw-thread to the cast-iron body. Weight of projectile 250 pounds.

FABRICATION OF THE GUN.

The steel tube was manufactured by the Bochum Steel Company, Bochum, Prussia, and was forged from a single ingot. The steel breech-block and breech-screw were obtained from Firth & Sons, Sheffield, England, the screw being tempered in oil. The tube was made of such extra thickness as to admit of being bored up to 10 inches, should the experience gained in the proposed trial of 250 rounds, and with a caliber of 9 inches, warrant such a course. The gun was manufactured at the West Point foundry, and being of a larger model than any previously cast there, some time was consumed in making the necessary preparations of plant, &c.

PITS AND FURNACES.

The gun-pits at this foundry are of masonry, and entirely above the foundry-floor. The one used in the present instance was in fair condition, and was heated by fire previous to casting. The furnaces employed for melting the iron—two in number—are above the pits, and rest on solid foundations of masonry and iron. The draught in these furnaces is produced by chimneys, instead of by a blast, hence they are termed air-furnaces.

THE IRON.

The iron used was Richmond (Mass.) charcoal-pig, such as has been mainly used in the fabrication of Rodman guns.

	Pounds.
One furnace was charged with	38,100
And the other with	27,100
Making a total of	65,200

For grading and detail of charges, see Table 1, giving foundry history of the gun.

THE MOLD.

The mold was formed in a flask in the ordinary manner, and suitable arrangements were made for cooling the gun from the interior. Advantage was taken of the fact that the gun was to be hollow throughout to cast the main portion of the breech hollow by lengthening out the core-barrel, as it was thought that by such method the faults incident to solid castings would be removed from that portion of the gun.

CASTING.

The fires were lighted at 2.30 a. m., and the metal was down by 11 o'clock. The metal was in fusion four hours, during which time it was tested every twenty minutes. At 3 p. m. it was deemed to be in excellent condition, and both furnaces were tapped at the same moment. The molten iron was conducted in runners from the furnaces to a suitable reservoir near the gun-mold, and from thence to a large trough to the gate of the mold. Twelve and one-half minutes were occupied in casting.

COOLING.

Water circulated through the core-barrel at the rate of thirty gallons per minute, entering at 38°, and leaving at 70°. One hour after casting the fires were lighted in the pit and kept replenished for forty-four

hours, after which they were allowed to die out. The water was shut off seventeen hours after casting, and the core-barrel removed one hour later, after which the water circulated through the gun, entering at 38°, and leaving after ebullition had ceased at 162°. The cooling progressed favorably, and was completed in eighty-six hours, or in one hundred and seven hours from the casting of the gun. Details of cooling are given in table.

BORING, TURNING, RIFLING, &C.

The gun was taken from the pit, cleaned from scale, and placed in a lathe, when the process of boring and turning was commenced. A ring 3¼ inches thick was cut off from next the muzzle, from which to ascertain the initial tension and afterwards to cut out specimens for mechanical tests. The specimens were taken from near the bore, the outside, and from two points intermediate. The results are shown in Table 1 as well as those obtained from the steel screw and breech-block. The gun having been turned to the prescribed dimensions without and rough-bored within, it was then finished-bored to a diameter of 14″.35 from the muzzle to a point 82 inches distant therefrom, and to a diameter of 16″.50 from the face of the breech through a distance of 102 inches. The remaining length of 5 inches was then turned in the form of a conic frustum, which united the larger and smaller portions of the bore. The pocket for the breech-block was then cut out by a tool specially designed for the purpose, after which the thread was cut in the breech for the reception of the breech-screw. The steel tube was next finished, bored, and chambered, then rifled, and turned on the exterior, the larger part to a diameter of 0″.005 less, and the smaller to a diameter 0″.007 less than the corresponding interior diameters of the casing. The relative diameters throughout the entire length of the tube are shown in table.

INSERTING THE TUBE.

To insert the tube in the cast-iron body, the latter was placed upon a heavy lathe-bed and firmly secured to it by heavy iron rods. The bore was then thoroughly cleaned, the exterior of the tube well oiled and then wiped off, and the tube inserted from the breech-end by means of a powerful hydraulic press. An enormous wrought-iron stirrup, embracing both gun and press, served to keep the piston and tube in the prolongation of the bore of the casing, and at the same time afforded the necessary support for the action of the press. As the tube was forced in, the resistance opposed by the casing increased in a steady ratio until the larger part of the tube reached to within 0″.05 of the beveled shoulder, when the pressure amounted to 3,000 pounds per square inch. The pressure was then taken off, and the gun removed to another lathe, where the breech-mechanism was finished and applied. The gun was then mounted on a carriage for a few preliminary rounds. The first round, with 35 pounds powder and projectile of 217 pounds, gave a pressure of nearly 6,000 pounds per square inch, owing to the large air-space, and failed to produce any change; a second round, with 40 pounds of powder and same weight of projectile as before, gave a pressure of 21,000 pounds, and forced the tube forward about 0″.04. A few additional rounds, with moderate charges, completed the work of setting the tube "home." The muzzle-collar was then screwed in, and the pins, to prevent the tube from turning in the casing, inserted. Both vents were furnished with the usual copper bushing; the gas-check, for which the tube was recessed, was of the Broadwell pattern, double-lipped.

INSPECTION.

The gun was inspected, and found to be sound and well finished in all its parts.

PRINCIPAL DIMENSIONS.

		Inches.
Exterior diameter of gun at muzzle		21.12
Exterior diameter 20 inches from muzzle		21.96
Exterior diameter 40 inches from muzzle		23.84
Exterior diameter 60 inches from muzzle		26.70
Exterior diameter 80 inches from muzzle		31.11
Exterior diameter 100 inches from muzzle		36.94
Exterior diameter of collar at breech		25.97
Exterior diameter 20 inches from breech		46.74
Exterior diameter 30 inches from breech		46.84
Exterior diameter maximum		47.38
Diameter of bore		9.00
Diameter of chamber		9.30
Diameter of gas-check, exterior		12.50
Diameter of trunnions		13.00
Diameter of rimbases		15.00
Diameter of breech-block		16.50
Diameter of breech-screw, exterior, with threads		18.00
Diameter of breech-screw, omitting threads		16.50
Diameter of breech-screw, interior		9.70
Diameter of breech-screw collar		22.00
Diameter of vents		0.20
Thickness of tube, (greatest)		3.75
Thickness of tube, (least)		2.625
Distance between rimbases		48.10
Distance from face of muzzle to center of trunnions		118.70
Distance from face of breech to center of trunnions		66.70
Total length of gun, cast-iron part		183.40
Length of rifled portion of bore, including bevel		27.00
Length of chamber, exclusive of bevel on lands		120.50
Length of beveled junction of chamber and bore, top		3.50
Length of beveled junction of chamber and bore, bottom		1.75
Total length of bore		147.50
Length of breech-screw, including shoulder		28.50
Thickness of breech-block, in direction of bore		12.40
Length, in direction of bore, of pocket		12.85
Number of lands	36	
Number of grooves	36	
Depth of grooves		0.09
Width of lands, at chamber		0.2920
Width of lands, at muzzle		0.3920
Weight of cast-iron body	37,550	pounds.
Weight of steel tube	5,012	"
Weight of steel breech-screw	1,471	"
Weight of steel breech-block	638	"
Weight of steel obdurator plate	111	"
Weight of steel gas-check	22	"
Total weight of gun complete	44,804	"

Preponderance, *nil.*

THE CARRIAGE.

The carriage devised for this gun was obtained by altering the ordinary 15-inch carriage to fit the smaller dimensions of the gun. These alterations consisted chiefly in shortening the transoms of top-carriage and chassis, and reducing the size of the trunnion-beds. An elevating rack and friction recoil-check, such as were used on the carriage of experimental gun No. 1, were then attached, and the carriage was ready for the reception of the gun.

EXPERIMENTS AND TESTS.

This gun has been fired at Sandy Hook, under the direction of the Ordnance Board, 26 rounds, the record of which is appended.

THE POWDER.

Du Pont's hexagonal F. U. E. V., density, 1.75.
Du Pont's hexagonal F. U. E. V., granulation, 72 to the pound.
Du Pont's hexagonal G. H. F. P., density, 1.785.
Du Pont's hexagonal G. H. F. P., granulation, 72 to the pound.
Frankford Arsenal, prismatic, density, 1.72.
Frankford Arsenal, prismatic, granulation, 11.3 to the pound.
German, prismatic, density, 1.64 to 1.68.
German, prismatic, granulation, 11.8 to the pound.
The gun is now on exhibition at Philadelphia.

PROCESS OF LEAD-COATING PROJECTILES, CHEMICALLY, (COMPILED FROM REPORTS PUBLISHED IN THE RUSSIAN ARTILLERY JOURNAL.)

1. The projectiles must be turned off smoothly and brightly.
2. Keep them in a pickle or solution of zinc and vitriol, (proportion three pounds of zinc to each pound of vitriol,) until they show a metallic appearance; about 20 pounds of vitriol to 100 shells of nine pounds, and enough water to cover the surface to be coated; the projectiles being set upright in a wooden box lined with lead. The zinc prevents the acid from acting too violently on the iron.
3. After the pickle, immerse them in clear water, and then in a bath of one pound of lime to 2¾ gallons of water.
4. Rub the surface with rags and sand until a clear metallic appearance shows itself; wipe dry with rags and saw-dust; brush off the saw-dust.
5. Heat the projectiles to that degree that a drop of water thrown on them will boil at once.
6. Dip them in a solution of one part of sal-ammoniac to four parts of water, (hot.)
7. Then cover them with a thick layer of powdered sal-ammoniac.
8. Being perfectly dry, dip them into the molten zinc until they have the same temperature as the zinc.
9. Wipe off the dripping zinc with gloves previously saturated with the solution of sal-ammoniac. (6) The gloves must have dried without being wrung.
10. Cover them again with powdered sal-ammoniac.
11. Dip them into molten pewter for about half a minute. (For projectiles of hardened iron the coating with zinc is dispensed with.)
12. Wipe off the dripping pewter with the sal-ammoniac gloves.

13. Cover them again with the powdered sal-ammoniac.

14. Put them in the mold and pour the molten lead in.

The process to the zinc coating (8) is the same or similar to the galvanizing, only more caution is taken to have very smooth surfaces.

The process from the tin coating to the casting must be done quickly.

The mold for the final casting is of cast iron, made of two halves, working on a heavy hinge, and connected to a heavy bottom plate, and opened and shut by a pair of long handles. The inside must be polished. Its interior diameter must be a little longer than the diameter of the finished coated projectile.

The mold, prior to casting, is warmed so that drops thrown on will boil at once, and receives a coating of grease, which should be allowed to dry before casting.

The casting is tested by making incisions which will show whether it adheres firmly to the iron or will peel off.

The projectile is finished by turning off in the lathe the lead coating to the desired dimensions; prove them, and screw in the bottom or head screws.

S. CRISPIN,
Brevet Colonel of Ordnance, Constructor of Ordnance.

UNITED STATES ORDNANCE AGENCY, NEW YORK,
September 25, 1876.

TABLE NO. 1.—*Foundry history of the 9-inch Sutcliffe breech-loading rifle, Cold Spring, N. Y., December* 1, 1873.

Grade.	Charges of furnaces.		
	Furnace 1.	Furnace 2.	Total.
No. 1, green	6,300	4,500	10,800
No. 2, red	6,300	4,500	10,800
No. 3, white	14,800	10,500	25,300
Remelted	10,700	7,600	18,300
	38,100	27,100	65,200

	Coal consumed.		
	Furnace 1.	Furnace 2.	Total.
In melting	13,500	8,500	22,000
In fusion	6,100	4,350	10,450
	19,600	12,850	32,450

Record.

Furnaces fired at	3.00 a. m.
Metal down at	11.05 a. m.
Gun cast at	3.00 p. m.
Time in fusion	3 55 h.
Time occupied in casting	12½ minutes.
Temperature of water entering core barrel	38 degrees.
Temperature of water leaving in 30 minutes	70 degrees.
Rate of water per minute	30 gallons.

Fire kindled in pit	4.30 p. m.
Fire in pit burned	44 hours.
Water shut off	8.30 a. m.
Core barrel removed at	10.00 a. m.
Water injected into gun	12.00 m.
Rate of water per minute	14 gallons.
Temperature of water entering gun	38 degrees.
Water left gun in 15 minutes at	162 degrees.
Total time of cooling gun	105 hours.

Cooling-tables.—Core barrel.

Hour.	Temp.	Hour.	Temp.	Hour.	Temp.	Hour.	Temp.
	°		°		°		°
4 p. m	64	8 p. m	60	12 p. m	58	4 a. m	56
5 p. m	63	9 p. m	60	1 a. m	58	5 a. m	55
6 p. m	62	10 p. m	59	2 a. m	57	6 a. m	54
7 p. m	61	11 p. m	59	3 a. m	57	7 a. m	53
						8 a. m	53

Cooling-table.—Gun.

Temp.	Hour.	Temp.	Hour.	Temp.	Hour.	Temp.	Hour.	Temp.	Hour.	Temp.	Hour.	Temp.	Hour.	Temp.	Hour.	Temp.
°		°		°		°		°		°		°		°		°
158	11	102	21	77	31	60	41	53	51	45	61	44	71	42	81	40
148	12	98	22	75	32	59	42	52	52	45	62	44	72	42	82	40
140	13	95	23	74	33	59	43	50	53	45	63	44	73	42	83	40
132	14	92	24	72	34	58	44	50	54	45	64	44	74	42	84	40
125	15	.....	25	70	35	58	45	49	55	45	65	44	75	42	85	39
120	16	90	26	68	36	57	46	48	56	45	66	43	76	41	86	39
118	17	87	27	66	37	56	47	47	57	45	67	43	77	41	....	.....
114	18	84	28	64	38	55	48	46	58	44	68	43	78	41	....	.....
110	19	82	29	62	39	55	49	46	59	44	69	43	79	41	....	.....
106	20	80	30	61	40	54	50	46	60	44	70	42	80	41	....	.....

Mechanical tests, (iron and steel.)

Specimens.		Area of broken section, in inches.	Density.	Tenacity, pounds per square inch.
m	Inside	1.1159	7.3277	36,742
	Middle No. 1	1.1122	7.3053	31,469
	Middle No. 2	1.1144	7.3026	31,416
	Outside	1.1141	7.2998	33,216
tech-screw	No. 1	0.3147	7.8437	104,864
	No. 2	0.3132	7.8591	104,087
ech-block	No. 1	0.3167	7.8663	89,996
	No. 2	0.3132	7.8587	87,164

ese steel specimens it was observed that the absolute strength was from 1,000 to 3,000 pounds an the ultimate breaking weight; in other words the specimen *stretched* before breaking, a tough quality of steel. Elasticity and extensibility could not be tested as no specimens of ngth could be obtained.

Initial tension, (cast iron.)

Extension per inch of circumference.	Initial tension per inch.	Ratio of initial tension to strength of metal.
0.00092	16.500	0.4871

TABLE NO. 2.—*Relative diameters of bore of cast-iron body of 9-inch Sutcliffe gun and of steel tube for insertion therein, at different points of their cylindrical length.*

Smaller part.				Larger part.			
Inches from muzzle.	Interior diameter of casing.	Exterior diameter of tube.	Difference or play of tube.	Inches from breech of tube.	Interior diameter of casing.	Exterior diameter of tube.	Difference or play of tube.
75¼	14.245	14.240	0.005	66	16.483	16.480	0.003
74	.245	.240	.005	65	.488	.480	.008
73	.245	.240	.005	64	.487	.480	.007
72	.245	.240	.005	63	.488	.480	.008
71	.245	.240	.005	62	.488	.480	.008
69	.245	.240	.005	61	.488	.480	.008
68	.245	.240	.005	60	.488	.480	.008
67	.245	.240	.005	59	.488	.480	.008
66	.245	.240	.005	58	.488	.480	.008
65	.245	.240	.005	57	.488	.480	.008
64	.246	.240	.006	56	.488	.480	.008
63	.245	.240	.005	55	.488	.480	.008
62	.245	.240	.005	54	.488	.480	.008
61	.245	.240	.005	53	.488	.480	.008
60	.247	.240	.007	52	.487	.480	.007
59	.247	.240	.007	51	.487	.480	.007
58	.248	.240	.008	50	.487	.480	.007
57	.249	.240	.009	49	.486	.480	.006
56	.250	.240	.010	48	.486	.480	.006
55	.250	.240	.010	47	.486	.480	.006
54	.250	.240	.010	46	.486	.480	.006
53	.250	.240	.010	45	.486	.480	.006
52	.250	.240	.010	44	.486	.480	.006
51	.250	.240	.010	43	.486	.480	.006
50	.251	.240	.011	42	.486	.480	.006
49	.251	.240	.011	41	.486	.480	.006
48	.252	.240	.012	40	.486	.480	.006
47	.252	.240	.012	39	.486	.480	.006
46	.252	.240	.012	38	.486	.480	.006
45	.252	.240	.012	37	.486	.480	.006
44	.253	.240	.013	36	.486	.480	.006
43	.253	.240	.013	35	.486	.480	.006
42	.253	.240	.013	34	.486	.480	.006
41	.252	.240	.012	33	.486	.480	.006
40	.251	.240	.011	32	.486	.480	.006
39	.251	.240	.011	31	.486	.480	.006
38	.251	.240	.011	30	.486	.480	.006
37	.252	.240	.012	29	.486	.480	.006
36	.254	.240	.014	28	.486	.480	.006
35	.254	.240	.014	27	.486	.480	.006
34	.254	.240	.014	26	.486	.480	.006

Relative diameter of bore of cast-iron body of 9-inch Sutcliffe gun, &c.—Continued.

Smaller part.				Larger part.			
Inches from muzzle.	Interior diameter of casing.	Exterior diameter of tube.	Difference or play of tube.	Inches from breech of tube.	Interior diameter of casing.	Exterior diameter of tube.	Difference or play of tube.
33	.254	.240	.014	25	.486	.480	.006
32	.254	.240	.014	24	.486	.480	.006
31	.255	.240	.015	23	.486	.480	.006
30	.256	.240	.016	22	.486	.480	.006
29	.257	.240	.017	21	.486	.480	.006
28	.258	.240	.018	20	.486	.480	.006
27	.258	.240	.018	19	.486	.480	.006
26	.258	.240	.018	18	.486	.480	.006
25	.257	.240	.017	17	.486	.480	.006
24	.257	.240	.017	16	.485	.480	.005
23	.257	.240	.017	15	.486	.480	.006
22	.255	.240	.015	14	.485	.480	.005
21	.255	.240	.015	13	.485	.480	.005
20	.255	.240	.015	12	.485	.480	.005
19	.255	.240	.015	11	.485	.480	.005
18	.255	.240	.015	10	.485	.480	.005
17	.255	.240	.015	9	.485	.480	.005
16	.255	.240	.015	8	.485	.480	.005
15	.255	.240	.015	7	.485	.480	.005
14	.255	.240	.015	6	.485	.480	.005
13	.255	.240	.015	5	.485	.480	.005
12	.255	.240	.015	4	.485	.480	.005
11	.255	.240	.015	3	.485	.480	.005
10	.255	.240	.015	2	.485	.480	.005
9	.255	.240	.015	1	.486	.480	.006
8	.255	.240	.015	.....	.....	.....	.....
7	.255	.240	.015	.....	.....	.....	.....
6	.255	.240	.015	.....	.....	.....	.....
5	.255	.240	.015	.....	.....	.....	.....
4	.255	.240	.015	.....	.....	.....	.....
3	.255	.240	.015	.....	.....	.....	.....
2	.255	.240	.015	.....	.....	.....	.....
1	.255	.240	.015	.....	.....	.....	.....

The eccentricity of the smaller part of bore of casing for a distance of seventeen inches from the muzzle is .01, and is less at other points.

Record of firing with the 9-inch Sutcliffe experimental rifle No. 1, from November 11, 1874, to March 24, 1876, (inclusive,) at Cold Spring, N. Y., and Sandy Hook, N. J.

Date.	Number of shots.	Charge.				Projectile.				Mean observed velocities of the projectile at 110 feet from the muzzle of the gun, as recorded by Le Boulengé's chronograph.	Velocity at the muzzle.	Energy of projectile.		Gas pressure per square inch of surface of bore, as taken with Rodman's internal-pressure gauge.	Recoil of upper carriage.
		Kind of powder.	Cartridge.			Kind.	Weight.	Length.	Diameter.			Total at the muzzle. $\frac{WV^2}{2g}$	Per inch of the shot's circumference. $\frac{WV^2}{2g\,2\pi R}$		
			Weight.	Height.	Diameter.										
			Pounds.	*Inches.*	*Inches.*		*Pounds.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*	*Foot-lbs.*	*Foot-lbs.*	*Pounds.*	*Feet.*
November 11, 1874	1	Du Pont's hexagonal, F, U. E. V.	25	11.5	8.30	W.P. F., L.C.	217	.....	9.00	.....	.....	.....	.....	6,000	2.08
November 11, 1874	1	....do	35	15.5	8.30	....do	217	.....	9.00	.....	.....	.....	.....	21,000	4.16
November 11 and 13, 1874	3	....do	40	16.75	8.30	....do	217	.....	9.00	.....	.....	.....	.....	27,833	5.87
December 7, 1874	1	....do	35	15.5	8.30	....do	229	20.50	9.00	.....	.....	.....	.....	18,000	4.12
December 7 and 18, 1874, January 11, August 12, and November 27, 1875.	7	....do	40	16.75	8.30	....do	229	20.50	9.00	1,409	1,417	7,146,513	252,756	23,275	5.13
March 24, 1876	1	....do	40	16.75	8.30	Parker	250	21.5	8.96	1,186	1,192	5,520,920	195,263	23,500	3.42
March 24, 1876	1	....do	45	19.00	8.30	....do	250	21.5	8.96	1,299	1,306	6,627,417	234,397	23,500	4.00
December 18, 1875	1	....do	44¼	19.00	8.30	L. C.	229	20.5	9.00	.....	.....	.....	.....	26,500	6.10
October 28, 1875	2	G. H. F. P.	40	8.30	8.30	W. P. F	230	20.5	9.00	.....	.....	.....	.....	19,250	.....
March 18, 1876	2	Frankford Arsenal prismatic.	30	8.30	8.30	....do	229	20.5	9.00	1,299	1,307	6,080,628	215,031	25,500	3.07
November 4 and 5, 1875	4	German prismatic.	40	8.30	8.30	....do	229	20.5	9.00	1,381	1,389	6,866,870	242,865	17,000	5.46
March 24, 1876	2	....do	40	8.30	8.30	Gruson	244	21.5	9.00	1,327	1,334	6,748,703	238,686	29,250	3.79
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S. CRISPIN,
Lieutenant-Colonel of Ordnance, Constructor of Ordnance.

APPENDIX I.

Trial of the nine-inch coverted rifle, No. 3.

OFFICE OF THE BOARD ON EXPERIMENTAL GUNS, &c.,
New York City, June 28, 1876.

SIR: I have the honor to transmit herewith the report of the board on experimental guns, &c., of the trial of the 9-inch converted rifle No. 3.

Very respectfully, your obedient servant,

S. CRISPIN,
Brevet Colonel U. S. A., Lieutenant-Colonel of Ordnance,
President of the Board.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

REPORT OF THE TRIAL OF A 9-INCH RIFLE, CONVERTED FROM A 10-INCH CAST-IRON SMOOTH-BORE RODMAN GUN, BY LINING WITH A COILED WROUGHT-IRON TUBE INSERTED FROM THE MUZZLE; MADE IN CONFORMITY TO THE RESOLUTIONS OF THE BOARD ON HEAVY RIFLED ORDNANCE, INSTITUTED BY THE WAR DEPARTMENT UNDER THE ACT OF CONGRESS OF JUNE 6, 1872, FOR THE SELECTION OF BREECH-LOADING AND MUZZLE-LOADING RIFLED ORDNANCE FOR EXPERIMENTS AND TESTS.

The board on heavy rifled ordnance, instituted by the War Department under the act of Congress of June 6, 1872, for the selection of breech-loading and muzzle-loading rifled ordnance for experiments and tests, recommended, among other experiments, as follows:

"That in order to test the system of gun conversion by lining with wrought-iron and steel tubes, (as brought to the notice of the board in a communication addressed to the Chief of Ordnance by Maj. S. Crispin, and referred to the board by the ordnance department,) four 10-inch smooth-bore Rodman guns be converted to muzzle-loading rifles, using two calibers; two of the guns to have a caliber of not less than 8 inches, and two to have a caliber of not more than 9 inches. And, further, that two of the guns be converted by tubing from the rear, and two by tubing from the front; the character of the metal lining, whether steel or wrought iron, and the other details of conversion, to be determined by the War Department."

The decision of the board on heavy rifled ordnance, in this regard, having been approved, two 10-inch smooth-bore cast-iron Rodman guns were converted by lining them with wrought-iron coiled tubes, inserted at the muzzle, one to an 8-inch, and one to a 9-inch rifle, and were placed at the disposal of the board on experimental guns, &c., by the Chief of Ordnance, under date of October 22, 1874, with instructions to fire five hundred rounds, as contemplated by the board on rifling and venting, &c., convened under orders of the Department, dated March 29, 1873.

Five hundred and two rounds have been fired from the 9-inch rifle so converted, up to the date of this report, under the supervision of the board.

WROUGHT-IRON TUBING.

This gun was originally a smooth-bore, manufactured at Boston, inspected and proved in 1866. The cast iron has a density of 7.2636, and a tenacity of 32,538 pounds per square inch, and an initial tension of 10,000 pounds.

Plate No. I gives the general features of the gun as converted. Except in caliber and rifling, it conforms with the 8-inch gun No. 1, the exterior diameter of the wrought-iron tube being the same, while the caliber of the gun is one inch greater, the tube being 2″.25 thick, instead of 2″.75, as in the 8-inch gun. The gun is increased in weight 560 pounds by conversion, bringing the weight up to 15,600 pounds. The muzzle preponderance is 450 pounds.

For further description of the gun, see table No. 1.

CARRIAGE, (Plate No. II.)

The ordinary wrought-iron carriage for the service of the 10-inch smooth-bore Rodman gun in casemate was used during the tests. It consists of the upper carriage and chassis, the total weight being about 6,500 pounds; the upper carriage weighs 2,500 pounds, and the chassis 4,000 pounds. The trunnion-beds were practically deepened by means of wrought-iron pieces screwed on the upper trunnion-plates, their inner surfaces being tangent to the curve of the trunnion-beds at their greatest diameter.

The axis of the gun is 7 feet above the surface of its wooden platform. The upper carriage, consisting of two cheek-pieces connected by its trunnions, is attached in the rear by a strong cross-head transom to the piston-rod of a hydraulic buffer securely placed in the front of the chassis. The only changes in its construction are the ones necessitated by the modes adopted for checking recoil and for elevating and depressing the gun.

The following descriptions, in addition to Plate No. II, set forth these changes:

The recoil is checked by the hydraulic buffer. The principle of this buffer is as follows: the buffer consists of a cast-iron cylinder, having a total length of 78 inches, and closed at each end by a cast-iron cap firmly attached to the cylinder by a couple of screws. In the center of the rear cap there is a circular opening to allow the piston-rod to move in and out freely. The exterior and interior diameters of the cylinder are respectively 11 and 8 inches. At a distance of 16″.25 from the rear, and on the upper surface of the cylinder, there is a hole closed by a screw $\frac{3}{4}$ inch in diameter for the purpose of admitting the water, alcohol, glycerine, or whatever fluid may be used. A similar hole closed by a screw in the bottom of the front-cylinder cap permits the fluid to be withdrawn. The piston-rod is made of steel, has a diameter of 2″.25, and after passing through the rear cap is attached to the cross-head as above mentioned. The piston-head is of wrought iron, has a thickness of 2″.5, and fits easily in the cylinder. It is pierced with four holes near its circumference on opposite sides of the piston-rod. These holes have each an interior diameter of $\frac{7}{8}$ inch, which flares out both ways 2″.5. When the gun is fired, the fluid in the cylinder, being acted on by the piston-head, escapes sufficiently through the holes to allow the top carriage to move back without strain, and at the same time checks the recoil.

For elevating and depressing, the same apparatus as that employed with the 8-inch gun No. 1 was used, only differing in the mode of attach-

ment, which, in this case, was farther to the rear, to better overcome muzzle-preponderance. It consists of two circular-toothed arcs, having their centers at the axis of the trunnions, (one on each side,) attached to the gun. A wrought-iron axle passing through the cheek-plates, has, at one end, a hand-wheel. By simple, multiplied gearing, power is transmitted to the toothed segments. (See plate No. II.) This arrangement admits of 30° of elevation and 14° of depression.

The means for loading and running the gun and carriage in and out of battery and traversing, remain unchanged from the original system of 10-inch smooth-bore carriages. The ordinary service pintle and strengthened pintle transom (2 inches thick) were used in the experiments.

POWDER.

The powder used during these tests was the Du Pont hexagonal, with the exception of four rounds of Oriental hexagonal, fired in the rounds. from 154 to 157, inclusive.

The powder being made in separate lots, indicated occasional variations in pressures and velocities.

The densities of the Du Pont powder were 1.750 and 1.785.

Plate No. V, appended to report of 8-inch gun No. 1, gives the shape, dimensions, and weight of grains.*

The friction-primers were manufactured at Frankford Arsenal, and worked well.

The cartridge-bags were of woolen serge, and had a windage of 1″.

PROJECTILES.

The projectiles used in the experiments were elongated cast-iron cored shot, with soft metal bases to take the grooves and insure rotation. Three kinds were used, Arrick, Butler, and Dana.

Table No. 1 shows that 83 Arrick, 300 Butler, and 117 Dana projectiles were fired. This table also gives their weights. Extracts 1 and 2, being carefully prepared analyses of the performances of these projectiles in the 8-inch and 9-inch guns, give, in a condensed form, an idea of their comparative merits.

EXPERIMENTS AND TESTS.

Eight preliminary rounds, (see Table No. 1, from 1 to 8 inclusive,) using 25, 30, 35, and 40 pounds of powder and projectiles of 215 pounds, were fired, to note pressures and velocities, to set up the tube, and to observe the effects upon gun and carriage. The results of this firing being satisfactory, it was continued to the eighteenth round with charges of 40, 45, and 35 pounds of powder, when the board resolved upon the following programme, viz:

45 pounds of powder for projectiles weighing 200 to 215 pounds.
40 pounds of powder for projectiles weighing 230 pounds.
35 pounds of powder for projectiles weighing 250 pounds.

"The intention is to reach 6,000,000 foot-pounds or thereabouts. If the pressures should run over 30,000 pounds, the powder should be first changed, and, if proper pressures are not obtained, then the firing must be stopped." (Proceedings of the board, August 17, 1875.)

* See page 101, Report of Chief of Ordnance for 1875.

TABLE No. 1.—*Record of firings for endurance with a 9-inch experimental rifle, from August 16 to December 4, 1875, inclusive, at Sandy Hook, N. J.*

Description of gun.—A rifle converted from a 10-inch cast-iron smooth-bore, by lining with a wrought-iron tube inserted at the muzzle; caliber, 9 inches; total length of gun, 136.66 inches; length of bore, 117.25 inches; length of rifling, 106.25 inches; diameter of bore, including grooves, 9″.16; number of grooves and lands, 17 each; width, (equal,) 0″.8316; depth of grooves, 0″.08; twist, uniform, one turn in 45 feet.

Dates.	Number of shots.	Charge.				Projectile.				Mean observed velocities of the projectile at 110 feet from the muzzle of the gun, as recorded by Le Boulengé's chronograph.	Velocities at muzzle.	Energy of projectile.		Gas-pressure per square inch of surface of bore, as taken with Rodman's & Metcalfe's internal-pressure gauges.	Recoil of upper carriage.
		Kind of powder.	Weight.	Height.	Diameter.	Kind.	Weight.	Length.	Diameter.			Total at muzzle. $\frac{WV^2}{2g^*}$	Per inch of shot's circumference. $\frac{WV^2}{2g2\pi R}$		
			Pounds.	*Inches.*	*Inches.*		*Pounds.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*	*Ft.-lbs.*	*Ft.-lbs.*	*Pounds.*	*Feet.*
August 16	2	Du Pont's hexagonal, F. U. E. V.	25	14.	8.25	Butler	215	20.75	8.94	1,089	1,095	4,006,689	141,707	16,250	3.46
August 16	2	....do	30	16.25	8.25	..do	215	20.75	8.94	1,179	1,085	4,692,390	165,961	19,500	3.75
August 16	2	....do	35	18.50	8.25	..do	215	20.75	8.94	1,223	1,230	5,055,548	178,803	21,500	4.04
August 17	1	....do	35	18.50	8.25	..do	247	20.75	8.94	1,226	1,232	5,825,334	206,085	23,500	5.17
August 16 and 17	4	....do	40	20.75	8.25	..do	215	20.75	8.94	1,300	1,308	5,717,059	202,199	24,125	4.50
August 17, September 18, October 5, 8, and 26.	38	....do	40	20.75	8.25	..do	231	18.50	8.94	1,288	1,295	6,021,025	212,950	26,345	5.11
August 17	1	....do	40	20.75	8.25	..do	247	20.75	8.94	1,247	1,253	5,996,149	212,069	25,500	.....
September 6 and 7, and October 7 and 28.	30	....do	45	23.	8.25	..do	203	19.25	8.94	1,399	1,408	6,254,898	221,221	26,558	5.08
August 17, 26, and 27, and September 7, October 26, and November 27.	45	....do	45	23.	8.25	..do	213	20.75	8.94	1,379	1,388	6,377,896	225,572	26,433	4.94
October 22 and 23, and November 27.	11	....do	45	23.	8.25	..do	228	19.75	8.94	1,347	1,355	6,506,274	230,112	28,375	4.81
September 10 and October 5, 7, and 8.	30	....do	40	20.75	8.25	Arrick	225	19.50	8.95	1,280	1,287	5,792,400	204,828	24,900	5.42

TABLE No. 1.—*Record of firings for endurance with a 9-inch experimental rifle, &c.*—Continued.

Dates.	Number of shots.	Charge.				Projectile.				Mean observed velocities of the projectile at 110 feet from the muzzle of the gun, as recorded by Le Boulengé's chronograph.	Velocities at muzzle.	Energy of projectile.		Gas-pressure per square inch of surface of bore, as taken with Rodman's & Metcalfe's internal-pressure gauges.	Recoil of upper carriage.
		Kind of powder.	Weight.	Height.	Diameter.	Kind.	Weight.	Length.	Diameter.			Total at muzzle. $\frac{WV^2}{2g}$	Per inch of shot's circumference. $\frac{WV^2}{2g2\pi R}$		
			Pounds.	*Inches.*	*Inches.*		*Pounds.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*	*Ft.-lbs.*	*Ft.-lbs.*	*Pounds.*	*Feet.*
September 8 and 10, and October 7.	43	Du Pont's hexagonal, F. U. E. V.	45	23.	8.25	Arrick..	200	18.75	8.95	1,414	1,424	6,303,314	222,899	25,895	5.48
September 22 and October 5, 8.	35	....do	40	20.75	8.25	Dana...	230.5	18.50	8.94	1,260	1,266	5,766,833	203,959	25,657	5.09
September 9, and 10, and October 7.	43	....do	45	23.	8.25	..do	200	19.00	8.94	1,381	1,390	6,005,906	212,415	25,907	5.49
December 1	2	....do	45	23.	8.25	..do	230	20.00	8.94	.....	.....	.....	.....	32,000	5.58
October 22, November 20, and 24, and December 1.	7	Du Pont's hexagonal, F. P. G. H.	40	20.75	8.25	Butler ..	245	20.75	8.94	1,306	1,313	6,564,694	232,178	27,500	4.80
November 19	1	....do	41	21.20	8.25	..do	247	20.75	8.94	1,288	1,295	6,438,066	227,695	24,000	4.73
November 19	1	....do	43	22.10	8.25	..do	247	20.75	8.94	1,312	1,320	6,689,039	236,576	32,500	4.75
November 19, and 24, and December 3.	6	....do	45	23.	8.25	..do	202	19.25	8.94	1,418	1,428	6,402,163	226,430	23,500	4.73
November 19, 20, and 24, and December 3.	28	....do	45	23.	8.25	..do	212	20.75	8.94	1,423	1,432	6,756,797	238,972	26,625	4.74
October 22 and 29, and November 19, 20, 22, 23, 24, and 27, December 1.	77	....do	45	23.	8.25	..do	228	19.25	8.94	1,400	1,409	7,035,174	248,818	29,615	4.90
October 22 and November 19 ..	5	....do	45	23.	8.25	..do	245	20.75	8.94	1,348	1,355	6,991,391	247,269	31,000	4.79
November 19	3	....do	46	23.45	8.25	..do	228	19.25	8.94	1,383	1,391	6,856,588	242,502	30,833	4.85
November 19	2	....do	47	23.90	8.25	..do	213	20.75	8.94	1,438	1,448	6,941,218	245,495	31,200	4.69
September 21	5	....do	40	20.75	8.25	Arrick..	225	19.50	8.95	1,378	1,386	6,717,813	237,592	37,200	4.88

TABLE NO. 1.—*Record of firings for endurance with a 9-inch experimental rifle, &c.*—Continued.

Dates.	Number of shots.	Charge.				Projectile.				Mean observed velocities of the projectile at 110 feet from the muzzle of the gun, as recorded by Le Boulengé's chronograph.	Velocities at muzzle.	Energy of projectile.		Gas-pressure per square inch of surface of bore, as taken with Rodman's & Metcalfe's internal-pressure gauges.	Recoil of upper carriage.
		Kind of powder.	Weight.	Height.	Diameter.	Kind.	Weight.	Length.	Diameter.			Total at muzzle. $\frac{WV^2}{2g^*}$	Per inch of shot's circumference. $\frac{WV^2}{2g2\pi R}$		
			Pounds.	*Inches.*	*Inches.*		*Pounds.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*	*Ft.-lbs.*	*Ft.-lbs.*	*Pounds.*	*Feet.*
October 29, November 19, and December 1.	37	Du Pont's hexagonal, F. P. G. H.	45	23.	8.25	Dana...	230	18.50	8.94	1,373	1,381	6,817,643	241,124	29,713	5.08
December 3 and 4	2	Du Pont's hexagonal, E. V. G. I.	35	18.50	8.25	Butler..	245	20.75	8.94	1,295	1,302	6,470,391	228,843	32,500	4.71
December 3	5	....do	40	20.75	8.25	..do	212	20.75	8.94					31,000	4.73
September 21, and December 3.	20	....do	40	20.75	8.25	..do	226	19.25	8.94	1,407	1,416	7,042,938	249,092	32,111	4.93
December 3	5	....do	45	23.	8.35	..do	211	20.75	8.94	1,500	1,510	7,477,481	264,461	33,000	4.75
September 21	3	....do	40	20.75	8.25	Arrick..	225	19.50	8.95	1,412	1,421	7,061,381	249,745	35,000	5.17
September 21	2	Oriental hexagonal.	40	20.75	8.25	..do	225	19.50	8.95	1,395	1,403	6,883,619	243,458	36,500	5.37
September 21	2	....do	40	20.75	8.25	Butler..	230	20.75	8.94	1,385	1,393	6,936,638	245,333	37,750	5.56
	500														

* g is taken at 32.168 + for the latitude of New York City. Large share of tables worked by Mr. H. A. Sinclair.

REMARKS: Distance of first wire target from muzzle of gun, 60 feet; distance between first and second targets, 100 feet; mean weight of projectile, using battering charges, (45 pounds,) 215 pounds; mean velocity at muzzle, using battering charges, (45 pounds,) 1,403 feet; mean maximum pressure, using battering charges, (45 pounds,) 25,048 pounds; mean energy at muzzle, using battering charges, (45 pounds,) 6,577,678 foot-pounds; the maximum velocity at the muzzle, obtained with 45 pounds of powder and 200 pounds projectile, 1,424 feet. Maximum velocity at muzzle, obtained with 45 pounds of powder and 230 pounds projectile, 1,409 feet; the 228-pound projectiles were grouped with this lot. Butt, 200 feet from the muzzle of the gun.

N. B.—Four hundred and sixty-five shots were fired into the butt 200 feet distant from the muzzle of the gun. Twenty-two into a target 20 + 40 feet, at the distance of one mile from the gun; and thirteen others, for tests of flight, over the water, &c.

TABLE No. 2.—*Relative diameters of bore of cast-iron body of 10-inch gun and wrought-iron tube for insertion therein, at different points of their cylindrical length—9-inch converted rifle, No. 3.*

Inches from face of muzzle.	Interior diameter of bore.	Exterior diameter of tube.	Inches from face of muzzle.	Interior diameter of bore.	Exterior diameter of tube.
118	13.4965	13.4855	78	13.4965	13.4855
117	13.4965	14.4855	76	13.4965	13.4855
116	13.4965	13.4855	74	13.4960	13.4855
115	13.4965	13.4855	72	13.4960	13.4855
114	13.4965	13.4855	70	13.4960	13.4855
113	13.4965	13.4855	68	13.4960	13.4855
112	13.4965	13.4855	66	13.4960	13.4855
111	13.4965	13.4855	64	13.4960	13.4855
110	13.4965	13.4855	62	13.4960	13.4855
109	13.4965	13.4855	60	13.4960	13.4855
108	13.4965	13.4855	58	13.4960	13.4855
107	13.4965	13.4855	56	13.4960	13.4855
106	13.4965	13.4855	54	13.4960	13.4855
105	13.4965	13.4855	52	13.4960	13.4855
104	13.4965	13.4855	50	13.4960	13.4855
103	13.4965	13.4855	48	13.4960	13.4855
102	13.4965	13.4855	46	13.4960	13.4855
101	13.4965	13.4855	44	13.4960	13.4855
100	13.4965	13.4855	42	13.4960	13.4855
99	13.4965	13.4855	40	13.4960	13.4855
98	13.4965	13.4855	38	13.4960	13.4855
97	13.4965	13.4855	36	13.4960	13.4855
96	13.4965	13.4855	34	13.4960	13.4855
95	13.4965	13.4855	32	13.4960	13.4855
94	13.4965	13.4855	30	13.4960	13.4855
93	13.4965	13.4855	28	13.4960	13.4855
92	13.4965	13.4855	26	13.4960	13.4855
91	13.4965	13.4855	24	13.4960	13.4855
90	13.4965	13.4855	22	13.4960	13.4855
89	13.4965	13.4855	20	13.4960	13.4855
88	13.4965	13.4855	18	13.4960	13.4855
87	13.4965	13.4855	16	13.4960	13.4855
86	13.4965	13.4855	14	13.4960	13.4855
85	13.4965	13.4855	12	13.4960	13.4855
84	13.4965	13.4855	10	13.4960	13.4855
83	13.4965	13.4855	8	13.4960	13.4855
82	13.4965	13.4855	6	13.4960	13.4855
81	13.4965	13.4855	4	13.4960	13.4855
80	13.4965	13.4855	2	13.4960	13.4855

TABLE No. 3.—*Table of enlargements of 9-inch converted rifle No. 3.*

Inches from bottom of bore.	Original play of tube.	Original diameter of bore.	A.—Enlargement after 10 charges, 25 to 40 pounds.	Enlargement from column A, (after setting up of tube.)					Total enlargement after 500 rounds, including the setting up of tube.
				After a total of 105 rounds.	After a total of 213 rounds.	After a total of 300 rounds.	After a total of 404 rounds.	After a total of 500 rounds.	
11	0.011	8.987	0.016	0.007	0.016	0.017	0.017	0.017	0.0
13	0.011	8.987	0.017	0.006	0.016	0.016	0.016	0.016	0.0
15	0.011	8.987	0.017	0.006	0.016	0.016	0.016	0.016	0.0
17	0.011	8.987	0.015	0.005	0.015	0.155	0.016	0.016	0.0
22	0.011	8.989	0.008	0.010	0.020	0.021	0.025	0.026	0.0
27	0.011	8.989	0.003	0.015	0.016	0.018	0.023	0.025	0.0
32	0.011	8.989	0.001	0.008	0.012	0.012	0.013	0.017	0.0
37	0.011	8.989	0.000	0.005	0.008	0.008	0.008	0.008	0.0
43	0.0105	8.990	0.000	0.004	0.004	0.004	0.004	0.005	0.0
47	0.0105	8.989	0.000	0.0035	0.004	0.004	0.005	0.003	0.0
53	0.0105	8.989	0.000	0.001	0.003	0.003	0.003	0.004	0.0
57	0.0105	8.989	0.000	0.001	0.003	0.003	0.0035	0.004	0.0
63	0.0105	8.989	0.000	0.003	0.004	0.004	0.004	0.004	0.0
67	0.0105	8.989	0.000	0.003	0.003	0.0035	0.004	0.003	0.0
73	0.0105	8.989	0.000	0.003	0.003	0.003	0.003	0.003	0.0
77	0.0105	8.989	0.000	0.003	0.003	0.003	0.003	0.003	0.0
87	0.0105	8.989	0.000	0.002	0.002	0.002	0.002	0.002	0.0
97	0.0105	8.985	0.003	0.002	0.002	0.002	0.002	0.002	0.0
107	0.0105	8.985	0.004	0.001	0.001	0.001	0.003	0.003	0.0
116	0.0105	8.985	0.005	0.002	0.002	0.002	0.002	0.002	0.0

TABLE No. 4.—*Showing the relative energies of the 9-inch United States rifled muzzle-loade (converted) and the 9-inch English rifled muzzle-loader of 12 tons, at distances up t 1,800 yards.*

Range.	*9-inch rifled muzzle-loader of 12 tons, charge 50 pounds, projectile 250 pounds.			9-inch United States rifled muzzle-loader (converted) No. 3, charge 45 pounds.		
	Velocity.	Total energy.	Energy per inch of shot's circumference.	Velocity.	Total energy.	Energy per inch of shot's circumference.
Yards.	*Feet.*	*Foot-tons.*	*Foot-tons.*	*Feet.*	*Foot-tons.*	*Foot-tons.*
0	1,420	3,496	124.7	1,393	3,096.7	109.5
200	1,379	3,297	117.6	1,350	2,906.8	102.8
400	1,341	3,117	111.2	1,309	2,732.9	96.7
600	1,304	2,948	105.2	1,270	2,571.6	91.0
800	1,270	2,796	99.8	1,234	2,428.7	85.9
1,000	1,236	2,648	94.5	1,199	2,290.3	81.0
1,200	1,204	2,513	89.7	1,168	2,174.2	76.9
1,400	1,174	2,389	85.3	1,137	2,061.9	72.9
1,600	1,147	2,281	81.4	1,108	1,958.3	69.3
1,800	1,121	2,178	77.7	1,080	1,860.4	65.8

* Compiled from English tables.

TABLE NO. 5.—*Relative effectiveness of a 10-inch smooth-bore, and the same gun converted into a 9-inch rifle.*

Gun.		Weight of projectile.	Velocity at muzzle.	Penetration in unbacked armor-plates.	Energy at muzzle.	Foot-tons per inch of shot's circumference.				Relative accuracy at 1,000 yards.	Relative capacity of shell for bursting charge.
Kind.	Caliber.					At muzzle.	At 1,000 yards.	At 2,000 yards.	At 3,000 yards.		
	Inches.	*Pounds.*	*Feet.*	*Inches.*	*Ft.-tons.*						
Smooth-bore.....	10	127	1,600	7.30	2,255	73	36	20	14	1	1
Rifle.....	9	230	1,393	8.90	3,096	109	81	63	50	3	2

[Extract 1—Averages.]

EXPERIMENTS AND REPORTS WITH CANNON AND PROJECTILES—CLASSES 1, 4, AND 5.

Target record of firing with Butler and Dana 8-inch projectiles, at Sandy Hook, N. J., from April 24 to November 5, 1875.

Number of fire.	Date.	Powder.		Projectile.		Elevation.	Pounds pressure per square inch of bore.	Initial velocity.	Recoil.	Wind, strength and direction.	Powder lot.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
		Kind.	Weight.	Kind.	Weight.							
			Lbs.		*Lbs.*			*Feet.*	*Feet.*		*No.*	
Rounds 533 to 538, inclusive.	April 24	Du Pont's hexagonal. E. V. (F.U.)	35	Dana	180	1¼°	36,600	1,358	3.73	Light, S. W	13	533 to 537, inclusive, fired into sand-butt. Sabots, as a rule, scored off in passing through sand. 538 fired over water, elevation 10°; clear, smooth sound.
Rounds 561 to 570, inclusive.	August 7	do	35	do	180	1°	29,650	1,320	3.59	Light, S	9	All the sabots stripped or tore off in butt, being put on loosely; in nearly every case they had to be "set up" with a hammer, which upset them to a degree that caused difficulty in loading.
Rounds 591 to 600, inclusive.	August 11	do	35	do	180	1°	29,250	1,311	3.64	Light, S. E	8	Fired into butt, projectile taking grooves well, but stripping in the butt.
Rounds 613, 615, 618, and 621.	August 12	do	35	do	180	3° 1′	(*)	(*)	3.32	Light, N. W	7	Fired at target. Round 618 sabot stripped in flight.
Rounds 628 to 632, inclusive.	August 13	do	35	do	180	5°	(*)	(*)	3.13	Brisk, S	7	Sabots did not strip. Clear, smooth sound. Average range over water 2,604 yards.
Rounds 643 to 647, inclusive.	August 13	do	35	do	180	10°	(*)	(*)	2.89	do	7	Sabots did not strip. Clear, smooth sound. Average range over water 4,428 yards.
Rounds 653 and 656.	August 14	do	35	do	180	3° 10′	(*)	(*)	3.71	Light, S. E	10	Fired at target. Projectiles took grooves well,

Rounds 712, 715, 718, 721, 724, 727, 730, 733, 736, 739, 742, 745, and 748.	November 3 and 5	....do	35	..do	180	3° 5′	(*)		3.23	Light and shifting...	9	Fired at target. Rounds 718 and 730 sabots stripped in flight, the rest had a clear, smooth sound.
Rounds 571 to 580, inclusive.	August 9.....	....do	35	Butler ..	180	1°	30,700	1,349	3.44	Brisk, S. E.....	9	Fired into sand-butt. Projectiles took grooves well, and did not strip in butt.
Rounds 601 to 610, inclusive.	August 12.....	....do	35	..do	180	1°	28,850	1,338	3.75	Light, S. E.....	8	Fired into sand-butt. Projectiles took grooves well, and did not strip in butt.
Round 616	August 12.....	....do	35	..do	180	2° .55	(*)	(*)	3.46	....do	7	Fired at target. Projectile took grooves well. Clear, smooth sound.
Rounds 619 and 622	August 12.....	....do	35	..do	180	3°	(*)	(*)	3.21	....do	7	Fired at target. Projectiles took grooves well.
Rounds 633 to 637, inclusive.	August 13.....	....do	35	..do	180	5°	(*)	(*)	3.06	....do	7	Fired over water. Clear, smooth sound. Average range 2,608 yards.
Rounds 648 to 652, inclusive.	August 13.....	....do	35	..do	180	10°	(*)	(*)	2.77	....do	7	Fired over water. Clear, smooth sound. Average range 4,390 yards.
Round 655	August 14.....	....do	35	..do	180	3°	(*)	(*)	3.62	Light, S	10	Fired at target. Projectile took grooves well. Clear, smooth sound.
Round 658	August 14.....	....do	35	..do	180	3° 10′	(*)	(*)	3.42	....do	10	Fired at target. Projectiles took grooves well. Clear, smooth sound.
Rounds 711, 714, 717, 720, 723, 726, 729, 732, 735, 738, 741, 744, and 747.	November 3 and 5	....do	35	..do	180	3°	(*)	(*)	3.25	Light and shifting...	9	Fired at target. Projectiles took grooves well. Round 711 fired at 3° 5′. At rounds 735 and 744 projectiles weighed 181 pounds.
Number of shots fired.						GENERAL SUMMARY.						
Six	April 24.....	Du Pont's hexagonal. E. V. (F. U.)	35	Dana ..	180	1¼°	36,600	1,358	3.73	Light, S. W.....	13	Fired into sand-butt. Sabots stripped off in butt. One shot, fired over water at 10° elevation, gave a clear, smooth sound.

* Not taken.

Target record of firing with Butler and Dana 8-inch projectiles, &c.—Continued

Number of fire.	Date.	Powder.		Projectile.		Elevation	Pounds pressure per square inch of bore.	Initial velocity.	Recoil.	Wind, strength and direction.	Powder lot.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
		Kind.	Weight.	Kind.	Weight.							
			Lbs.		*Lbs.*			*Feet.*	*Feet.*		*No.*	
Twenty	August 7 and 11	Du Pont's hexagonal. E. V. (F. U.)	35	Dana	180	1°	29,450	1,316	3.62	Light, S. and S. E	9 & 8	Fired into sand-butt, all the projectiles taking grooves well, but stripping in butt; being put on loosely they had to be "set up" with a hammer, which upset the metal and caused a difficulty in loading.
Six	August 12 and 14	do	35	do	180	3° 10′	(*)	(*)	3.52	Light, N.W. to S.E.	7&10	Fired at target. One sabot stripped in flight, the rest took grooves well.
Ten	August 13	do	35	do	180	5° and 10°.	(*)	(*)	3.01	Brisk, S.	7	Fired over water. Sabot did not strip. Clear, smooth sound. Average ranges at 5° and 10°, 2,604.8 and 4,428 yards, respectively.
Thirteen	November 3 and 5	do	35	do	180	3° 5′	(*)	(*)	3.23	Light and shifting	9	Fired at target. Two sabots stripped in flight, the rest had a clear, smooth sound. One shot weighed 181 pounds.
Twenty	August 9 and 12	do	35	Butler	180	1°	29,775	1,344	3.60	Brisk to light, S. E.	9 & 8	Fired into sand-butt. Projectile took grooves well, and did not strip in butt.
One	August 12	do	35	do	180	2° 55′	(*)	(*)	3.46	Light, S. E.	8	Fired into sand-butt. Projectiles took grooves well, and did not strip in butt.
Four	August 12 and 14	do	35	do	180	3° 3° 5′ 3° 10′	(*)	(*)	3.42	Light, S. E. to S	7&10	Fired at target. Projectiles took grooves well. Clear, smooth sound.

Ten	August 13	do	35	do	180	5&10°	(*)	(*)	2.92	Light, S. E.	7	Fired over water. Clear, smooth sound. Average ranges 2,608 and 4,390 yards, respectively.
Thirteen	November 3 and 5	do	35	do	180	3°	(*)	(*)	3.25	Light and shifting	9	Fired at target. Projectiles took grooves well. One round fired at 3° 5′. Two projectiles weighed each 181 pounds.

* Not taken.

[Extract 2—Averages.]

EXPERIMENTS AND REPORTS WITH CANNON AND PROJECTILES—CLASSES 1, 4, AND 5.

Target record of firing with Dana and Butler projectiles, at Sandy Hook, N. J., from September 7 to October 5, 1876.

Number of fire.	Date.	Powder.		Projectile.		Pounds pressure per square inch of bore.	Initial velocity.	Recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
		Kind.	Weight.	Kind.	Weight.				
			Lbs.		*Lbs.*		*Feet.*	*Feet.*	
Rounds 106 to 115, inclusive..	September 10	Dupont's hexagonal, F. U. E. V	45	Dana ...	200	24,750	1,343	5.41	Fired into sand-butt. Projectiles took grooves well.
Rounds 35 to 44, inclusive....	September 7	.....do	45	Butler ..	203	25,250	1,383	5.02	Do.
Rounds 131 to 134, inclusive..	September 18	.....do	40	..do	234	25,875	1,305	4.75	Do.
Rounds 169 to 172, inclusive..	October 5	.....do	40	Dana ...	231	24,000	1,259	4.94	Do.

10 INCH RODMAN S.B. GUN CONVERTED INTO AN 9 INCH M.L. RIFLE

by lining with a jacketed wrought iron tube inserted at the muzzle.

Fig. 3.

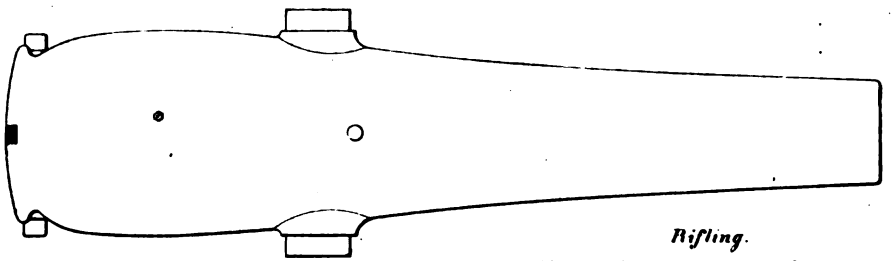


Fig. 1.

Rifling.

Twist uniform, one turn in 45 feet.
17 Grooves and Lands, each 0.8516 inch wide.
Grooves 0.08 inch deep.
Weight: 15600 lbs

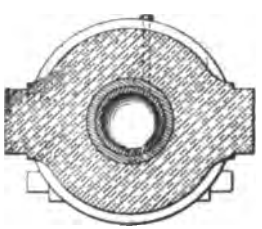


Fig. 4.

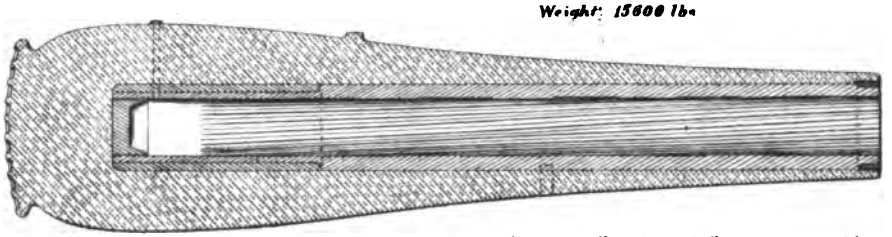


Fig. 2.

Scale

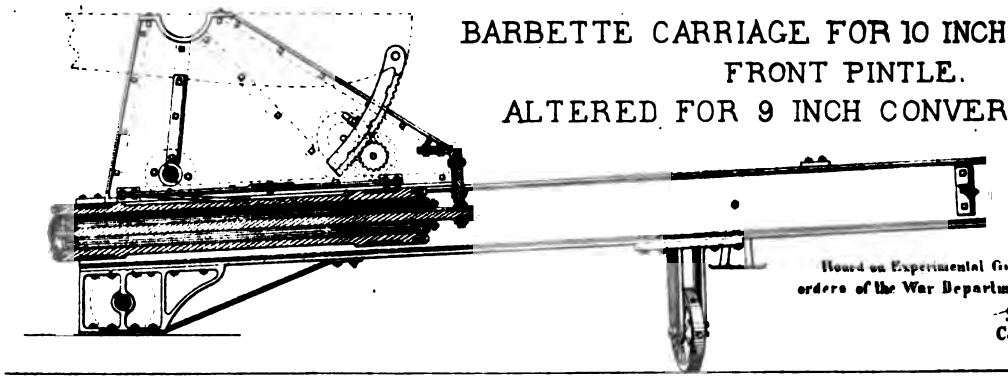
10 5 0 10 20 30 40 50 60 Inches.

Board on Experimental Guns etc. convened by orders of the War Department dated October 10th 1876.

Geo. W. McKee
Captain of Ord. Recorder.

Plate I.

BARBETTE CARRIAGE FOR 10 INCH RODMAN GUN.
FRONT PINTLE.
ALTERED FOR 9 INCH CONVERTED RIFLE.



Board on Experimental Guns etc. convened by orders of the War Department dated October 10, 1874.

Geo. W. McKee
Captain of Ordnance Recorder.

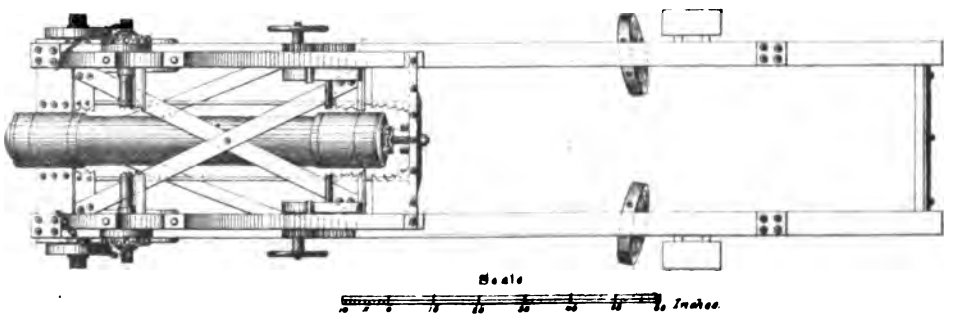


Plate. I.

APPENDIX K.

Trial of the eight-inch converted rifle No. 2.

OFFICE OF THE ORDNANCE BOARD, U. S. A.,
New York City, September 25, 1876.

SIR: I have the honor to transmit herewith the report of the ordnance board on the trial of 8-inch converted rifle No. 2.

Very respectfully, your obedient servant,

S. CRISPIN,
Brt. Col. U. S. A., Lieut. Colonel of Ordnance,
President of the Board.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

THE GUN.

The history of this gun and the details of its construction are given in the report of the Constructor of Ordnance of September 25, 1876.

The accompanying plates Nos. I, II, and III show the construction of the gun, and its condition at different stages of its trial.

CARRIAGE.

For description of carriage, see remarks under this head in report of 9-inch gun No. 3. The carriages were identical, with exception of device for preventing the gun jumping out of the trunnion-beds, this being unnecessary in the case of the 8-inch gun No. 2.

PLATFORM.

The details of the wooden platform used are given in Plate IV.

POWDER.

The powder used in the trials was the Du Pont hexagonal, specific gravity 1.75, hitherto described in the report of 8-inch gun No. 1.

PROJECTILE.

The projectile used in the experiments was the Butler cast-iron cored shot, with a double-lipped sabot, previously described in report of 8-inch gun No. 1. It worked smoothly, and gave general satisfaction. No other projectiles were fired, as they could not be obtained in time for the experiments.

ACCURACY AND RANGE.

After the completion of the one hundred and seventieth round, the board resolved, on April 28th, 1875, to continue the firing of the gun with 35 pounds of powder and projectiles weighing 165 to 180 pounds, to complete a record of 452 rounds.

"On the completion of this programme 48 rounds, (to complete the series to 500 rounds with this gun,) to be fired in the presence of the board, making a record with as many rounds as may be determined upon of accuracy and range, with both kinds of projectiles; the whole programme, of course, contingent on the endurance and serviceableness of the gun."

Although the breaking of the gun prevented the completion of this programme to 500 rounds, enough was observed, from the few trial-shots fired previous to its rupture, at the target and at sea, to warrant the belief that, so far as accuracy and range are concerned, this gun was fully equal to the 8-inch gun No. 1.

EFFECTS ON CARRIAGE.

With the exception of two or three small bolts breaking during the course of the trials, nothing occurred to interfere with the proper working of the carriage. The delays occasioned thereby were insignificant, and scarcely interrupted the regular continuance of the firing.

GENERAL RECORD OF THE EXPERIMENTS AND TESTS.

The general record of gun No. 2 is as follows:

Six preliminary rounds were fired, using charges ranging from 20 to 30 pounds, as in gun No. 1. Four hundred and fifty rounds were fired with battering-charges of 35 pounds of hexagonal powder and an average weight of projectile (Butler) of 171 pounds.

All examinations up to the one hundred and seventieth fire failed to discover any evidence of injury to the system; but impressions taken of the bore at this round showed a fine line extending from the commencement of the land immediately in front of the vent to the copper bushing. This proved to be an initial rupture, as at 175 rounds a crack had developed from the vent to the muzzle in and through the tube. The firings were continued from this point up to the four hundred and fifty-sixth, (the breaking round,) making a total of 286 rounds which the system endured after the rupture of the tube.

The gun was fired after the complete rupture of the inner tube—at the one hundred and seventy-fifth round—to test how long the jacket and the cast-iron casing would stand battering-charges. Evidence of rupture of the jacket were noted at the last few rounds, and the gun, when burst, evidently was being held together by a weakened cast-iron casing, probably cracked on its interior surface.

The steel in both jacket and tube, although of good quality (see report of construction of gun) was evidently too high and inextensible to secure the very best results.

An analysis of the record shows as follows: A mean initial velocity of 1,379 feet, using 35 pounds powder and projectile of about 185 pounds; the mean maximum pressure being 30,453 pounds per square inch, and, for a shot of 170 pounds, a velocity of 1,425 feet, and a corresponding mean maximum pressure of 29,622 pounds. Forty-six shots of about the weight of the former, and 283 shots of about the weight of the latter, were fired.

The mean weight of all projectiles—using 35-pound charges—is 171 pounds; the mean velocities and pressures obtained are, respectively, 1,419 feet and 29,668 pounds.

No anomalies are apparent in these respects, and the record shows a

general accordance with the results attained in the trial of the 8-inch rifle No. 1.

The star-gauging at the one hundred and seventieth round indicated a maximum enlargement of 0″.010; at the one hundred and seventy-fifth round, of 0″.0115, the result of the crack; from this point to the four hundred and fifty-second round, the maximum enlargement was 0″.0235. (See Table No. 4.)

The gutta-percha impressions taken at various times during the progress of the trial indicated no special erosion from the gases; but, as the firings progressed, spawls were gradually developed along the line of the crack in the tube.

CONCLUSIONS.

The results now before the Department, obtained by the tests of guns No. 1 and No. 3, and the ones herein submitted of gun No. 2, although not affording conclusive evidence as to the most perfect methods of conversions as far as systems are concerned, yet undoubtedly point to the superior quality of coiled wrought-iron tubes over steel ones for 8-inch conversions.

The system tried in this gun is, (in the opinion of the board, based upon the results attained and upon theoretical considerations;) one of great strength in itself, and as it admits of the use of wrought-iron lining, the board deems the present experiments now in progress with the converted 9-inch rifle upon this plan as likely to afford valuable information as to mode of lining our cast-iron guns, either for conversions or original constructions.

S. CRISPIN,
Brevet-Colonel, U. S. A., Lieutenant-Colonel of Ordnance,
President of the Board.
T. J. TREADWELL,
Major of Ordnance.
T. G. BAYLOR,
Major of Ordnance.
GEO. W. McKEE,
Captain of Ordnance, Recorder.

TABLE No. 1.—*Record of firings for endurance with an 8-inch experimental rifle (No. 2) from April 19 to June 3, (inclusive,) 1875, at Sandy Hook, N. J.*

Description of gun.—A rifle converted from a 10-inch Rodman cast-iron smooth-bore by lining with a jacketed steel tube inserted from the breech. Caliber, 8 inches; total length of gun, 155.16 inches; length of bore, 127.78 inches; length of rifling, 117.25 inches; diameter of bore, including grooves, 8.15 inches; number of grooves and lands, 15 each; twist uniform, one turn in 40 feet; weight of gun, 16,400 pounds.

Date.	Number of shots.	Charge.				Projectile.				Mean observed velocities of the projectile at 110 feet from the muzzle of the gun, as recorded by the Le Boulengé chronograph.	Velocities at the muzzle.	Energy of projectile.		Gas pressure per square inch of surface of bore, as taken with Rodman's internal-pressure-gauge.	Recoil of upper carriage.
		Kind of powder.	Cartridge.									Total at the muzzle.	Per inch of the shot's circumference.		
			Weight.	Height.	Diameters.	Kind.	Weight.	Length.	Diameters.			$\frac{PV^2}{2g}$	$\frac{PV^2}{2g2\pi R}$		
			Pounds	*Inches.*	*Inches.*		*Pounds.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*	*Foot-lbs.*	*Foot-lbs.*	*Pounds.*	*Feet.*
May 25 and June 3	7	Dupont's hexagonal, F. U. E. V. Spec. gravity, 1.750.	35	22	7.15	Butler	166	.....	7.95	1,408	1,417	5,175,614	207,226	26,000	4.74
May 15 and 25, and June 1	17		35	22	7.15	...do	167	.....	7.95	1,377	1,385	4,974,434	199,171	28,642	4.68
April 21, 22, and 23, and May 8, 14, 15, 24, and 25, and June 3	61		35	22	7.15	...do	168	.....	7.95	1,426	1,435	5,371,891	215,091	30,222	4.37
April 21, 22, and 23, and May 8, 14, 15, 22, 24, 25, 26, 29, and June 1	76		35	22	7.15	...do	169	.....	7.95	1,388	1,397	5,121,458	205,063	29,483	4.80
April 19, 20, 21, 22, and 23, and May 4, 8, 13, 14, 15, 22, and 29	157		35	22	7.15	...do	170	.....	7.95	1,431	1,440	5,473,789	219,171	30,232	5.03
April 19, 21, 22, and 23, and May 4, 8, 14, 15, 22, 25, and 29	34		35	22	7.15	...do	171	.....	7.95	1,418	1,427	5,407,023	216,497	28,000	4.87
April 22 and May 14, 15, 25, and 29	16		35	22	7.15	...do	172	.....	7.95	1,397	1,406	5,279,748	211,401	27,750	5.03
May 15 and 25	13		35	22	7.15	...do	173	.....	7.95	1,387	1,396	5,235,173	209,616	29,000	5.12
April 19 and 22, and May 25	5		35	22	7.15	...do	174	.....	7.95	1,406	1,415	5,440,829	217,851	27,750	4.46
April 21 and May 25	5		35	22	7.15	...do	175	.....	7.95	1,415	1,424	5,510,261	220,631	31,100	4.92
April 19 and 20, and May 29	5		35	22	7.15	...do	184	.....	7.95	1,395	1,405	5,640,071	225,829	30,833	4.31
April 20 and May 26 and 29	24		35	22	7.15	...do	185	.....	7.95	1,365	1,373	5,415,355	216,831	31,529	4.75

April 20 and May 29	15	35	22	7.15	...do....	186	.....	7.95	1,383	1,390	5,580,299	223,435	29,200	4.71
May 29	2	35	22	7.15	...do....	187	.....	7.95	1,306	1,313	5,161,214	206,655	26,000	4.47
April 22 and May 14, 15, 25, and 29	13	35	22	7.15	...do...	*163	.....	7.95	(†)	.....	.....	.....	.....	4.79
Total	450													

* Average. † Omitted.

REMARKS.—Distance of the first wire target from the muzzle of the gun, 60 feet; mean weight of projectile, using battering-charges, (35 pounds,) 171 pounds; mean velocity at muzzle, using battering-charges, (35 pounds,) 1,419 feet; mean maximum pressure, using battering-charges, (35 pounds,) 28,668 pounds; mean energy at muzzle, using battering-charges, (35 pounds,) 5,341,940 pounds; mean recoil of upper carriage, 4.73 feet; butt 200 feet from muzzle of the gun.

Four hundred and thirty-eight shots were fired into the butt, eleven others for test of flight over water, &c., and one into a target at the distance of one mile from the gun.

The lots of powder tested in their order on the record were Numbers 14, 17, 16, 15, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 0.

The record shows considerable variation in the strength of these lots.

TABLE No. 2.—*Record of firings with 8-inch experimental rifle No. 2 on April 19, 1875, at Sandy Hook, N. J.*

Date.	Number of shots.	Charge.				Projectile.				Velocities.	Maximum pressures per square inch at surface of bore.
		Kind of powder.	Cartridges.			Kind.	Weight.	Length.	Diameter.		
			Weight.	Height.	Diameter.						
			Lbs.	*Ins.*	*Ins.*		*Lbs.*	*Ins.*	*Ins.*	*Feet.*	*Lbs.*
April 19, 1875	1	Dupont's hexagonal F. U. E. V.	20	12.6	7.15	Butler.	167	.....	7.95	1,142	21,000
April 19, 1875	2		20	12.6	7.15	Butler.	168	.....	7.95	1,157	18,000
April 19, 1875	3		25	15.8	7.15	Butler.	170	.....	7.95	1,224	25,000
April 19, 1875	4		25	15.8	7.15	Butler.	170	.....	7.95	1,260	20,000
April 19, 1875	5		30	19.0	7.15	Butler.	170	.....	7.95	1,353	26,500
April 19, 1875	6		30	19.0	7.15	Butler.	170	.....	7.95	1,368	25,500

Remarks.—Distance from muzzle of the gun to the first wire target, 60 feet; distance between wire targets, 100 feet; distance from muzzle of the gun to butt, 200 feet. All these shots were fired into the butt, and were preliminary to the 450 rounds fired afterward to test the endurance of the gun.

TABLE No. 3, (Part I.)—*Table showing exterior diameter of tube and interior of jacket.*

Inches from breech.	Exterior diameter of tube.	Interior diameter of jacket.	Difference or shrinkage.	Inches from breech.	Exterior diameter of tube.	Interior diameter of jacket.	Difference or shrinkage.
45	12.014	12.0035	0.0105	22	12.014	12.0035	0.01[illegible]
44	12.014	12.0040	0.0100	21	12.014	12.0035	0.01[illegible]
43	12.014	12.0040	0.0100	20	12.014	12.0035	0.01[illegible]
42	12.014	12.0035	0.0105	19	12.014	12.0040	0.01[illegible]
41	12.014	12.0035	0.0105	18	12.014	12.0040	0.01[illegible]
40	12.014	12.0035	0.0105	17	12.014	12.0040	0.01[illegible]
39	12.014	12.0035	0.0105	16	12.014	12.0040	0.01[illegible]
38	12.014	12.0035	0.0105	15	12.014	12.0040	0.01[illegible]
37	12.014	12.0035	0.0105	14	12.014	12.0040	0.010[illegible]
36	12.014	12.0035	0.0105	13	12.014	12.0040	0.010[illegible]
35	12.014	12.0040	0.0100	12	12.014	12.0040	0.010[illegible]
34	12.014	12.0040	0.0100	11	12.014	12.0040	0.010[illegible]
33	12.014	12.0040	0.0100	10	12.014	12.0040	0.010[illegible]
32	12.014	12.0040	0.0100	9	12.014	12.0040	0.0100[illegible]
31	12.014	12.0035	0.0105	8	12.014	12.0050	0.009[illegible]
30	12.014	12.0035	0.0105	7	12.014	12.0050	0.009[illegible]
29	12.014	12.0035	0.0105	6	12.014	12.0050	0.0090[illegible]
28	12.014	12.0035	0.0105	5	12.014	12.0050	0.0090[illegible]
27	12.014	12.0035	0.0105	4	12.014	12.0050	0.0090[illegible]
26	12.014	12.0035	0.0105	3	12.014	12.0050	0.0090
25	12.014	12.0035	0.0105	2	12.014	12.0050	0.0090
24	12.014	12.0035	0.0105	1	12.014	12.0053	0.0090
23	12.014	12.0035	0.0105				

TABLE No. 3, (PART II.)—*Table showing interior diameter of cast-iron body and exterior diameter of steel tube and jacket prepared for insertion therein.*

Inches from muzzle.	Interior diameter of casing.	Exterior diameter of tube.	Difference or play of tube.	Inches from breech.	Interior diameter of casing.	Exterior diameter of jacket.	Difference or play of jacket.
82	12.000	11.993	0.007	56	15.985	15.980	0.005
81	12.000	11.993	.007	55	16.011	16.060	.005
80	12.000	11.993	.007	54	16.012	16.007	.005
78	12.000	11.993	.007	53	16.012	16.007	.005
76	12.000	11.993	.007	52	16.012	16.007	.005
74	12.000	11.993	.007	50	16.012	16.007	.005
72	12.000	11.993	.007	48	16.012	16.007	.005
70	12.000	11.993	.007	46	16.012	16.007	.005
68	12.000	11.993	.007	44	16.012	16.007	.005
66	12.000	11.993	.007	42	16.012	16.007	.005
64	12.000	11.993	.007	40	16.012	16.007	.005
62	12.000	11.993	.007	38	16.012	16.007	.005
60	12.000	11.993	.007	36	16.012	16.007	.005
58	12.000	11.993	.007	34	16.012	16.007	.005
56	12.000	11.993	.007	32	16.012	16.007	.005
54	12.000	11.993	.007	30	16.012	16.007	.005
52	12.000	11.993	.007	29	16.013	16.008	.005
50	12.000	11.993	.007	28	16.012	16.008	.005
48	12.000	11.993	.007	27	16.012	16.008	.005
46	12.000	11.993	.007	26	16.012	16.008	.005
44	12.000	11.993	.007	25	16.012	16.008	.005
42	12.000	11.993	.007	24	16.014	16.009	.005
40	12.000	11.993	.007	23	16.014	16.009	.005
38	12.000	11.993	.007	22	16.014	16.009	.005
36	12.000	11.993	.007	21	16.014	16.009	.005
34	12.000	11.993	.007	20	16.015	16.010	.005
32	12.000	11.993	.007	19	16.016	16.011	.005
30	12.000	11.993	.007	18	16.016	16.011	.005
28	12.000	11.993	.007	17	16.017	16.012	.005
26	12.000	11.993	.007	16	16.018	16.013	.005
24	12.000	11.993	.007	15	16.018	16.018	.005
22	12.000	11.993	.007	14	16.020	16.015	.005
20	12.000	11.993	.007	13	16.021	16.016	.005
18	12.000	11.993	.007	12	16.023	16.018	.005
15	12.000	11.993	.007	11	16.026	16.021	.005
12	12.000	11.993	.007	10	16.030	16.025	.005
10	12.000	11.993	.007	9	16.035	16.025	.010
8	12.000	11.993	.007	8	16.035	16.025	.010
6	12.000	11.993	.007	7	16.035	16.025	.010
4	12.000	11.993	.007	6	16.035	16.025	.010
2	12.000	11.993	.007	5	16.035	16.025	.010
1	12.000	11.993	.007	4	16.035	16.025	.010
				3	16.035	16.025	.010
				2	16.035	16.025	.010
				1	16.035	16.025	.010

TABLE No. 4.—*Table of enlargements of 8-inch converted rifle No. 2, (steel tube.)*

Inches from bottom of bore.	Original diameter of bore.	Enlargement after a total of 150 rounds.	Enlargement after a total of 175 rounds.	Enlargement after a total of 301 rounds.	Enlargement after a total of 452 rounds.
11	7.997	No enlargement...	.008	.014	.014
13	7.998	....do	.009	.015	.015
16	7.998	....do	.0095	.016	.016
19	7.998	....do	.0095	.016	.016
22	7.998	....do	.0095	.017	.017
25	7.998	....do	.0115	.022	.0235
28	7.998	....do	.011	.018	.021
31	7.998	....do	.008	.014	.016
34	7.998	....do	.005	.011	.012
37	7.998	....do	.0035	.008	.010
40	7.998	....do	.003	.008	.010
45	7.998	....do	.0045	.005	.007
50	7.998	....do	.0055	.006	.007
55	7.999	....do	.005	.0055	.009
60	8.005	....do	.005	.007	.013
65	8.006	....do	.003	.0085	.013
70	8.005	....do	.003	.011	.014
80	8.005	....do	.004	.013	.014
90	8.007	....do	.004	.011	.012
100	8.008	....do	.002	.011	.011
110	8.008	....do	.000	.009	.010
127	8.008	....do	.000	.002	.007

TABLE No. 5.—*Showing the relative energies of the 8-inch United States muzzle-loader rifle (converted No. 2,) and the 8-inch English rifle muzzle-loader of nine tons, at distances up to 1,800 yards.*

Range.	* 8-inch rifle muzzle-loader of 9 tons, charge 35 pounds; projectile 180 pounds.			8-inch United States rifle muzzle-loader (converted No. 2) 16,400 pounds, charge 35 pounds; projectile 186 pounds.		
	Velocity.	Total energy.	Energy per inch of shot's circumference.	Velocity.	Total energy.	Energy per inch of shot's circumference.
Yards.	*Feet.*	*Foot-tons.*	*Foot-tons.*	*Feet.*	*Foot-tons.*	*Foot-tons.*
0	1,413	2,492	100.2	1,390	2,491	99.7
200	1,369	2,339	94.0	1,348	2,343	93.8
400	1,327	2,198	88.3	1,309	2,209	88.0
600	1,286	2,064	83.0	1,272	2,086	84.0
800	1,248	1,944	78.1	1,237	1,973	79.0
1,000	1,213	1,837	73.8	1,204	1,869	74.8
1,200	1,180	1,738	69.9	1,172	1,771	70.9
1,400	1,150	1,651	66.3	1,142	1,682	67.3
1,600	1,122	1,571	63.2	1,114	1,600	64.0
1,800	1,097	1,502	60.4	1,086	1,521	61.0

* Compiled from English tables.
Remarks.—Fifteen rounds were fired with the 186-pound projectile.

TABLE No. 6.—*Relative effectiveness of a 10-inch smooth-bore, and the same gun converted into an 8-inch rifle.*

Gun.		Weight of shot.	Velocity at muzzle.	Energy at muzzle.	Penetration in unbacked armor-plates.	Foot-tons per inch of shot's circumference.				Relative accuracy at 1,000 yards.	Relative capacity of shell for bursting charge.
Kind.	Caliber.					At muzzle.	At 1,000 yards.	At 2,000 yards.	At 3,000 yards.		
	Inches.	*Pounds.*	*Feet.*	*Foot-tons.*	*Inches.*						
Smooth-bore	10	127	1,600	2,255	7.30	73	36	20	14	1	1
Rifle	8	186	1,390	2,491	8.46	100	75	58	46	3	2

10 INCH RODMAN S.B. GUN CONVERTED INTO AN 8 INCH M.L. RIFLE.

by lining with a jacketed steel tube inserted through the breech.

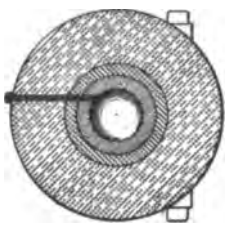


Fig. 3.

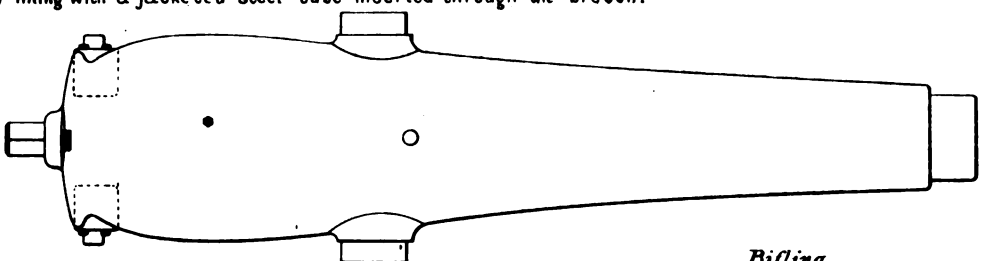


Fig. 1.

Rifling.

Twist uniform, one turn in 40 feet.

15 Grooves and Lands, each 0.55772" wide.

Grooves 0.075" deep.

Weight 16400 lbs.

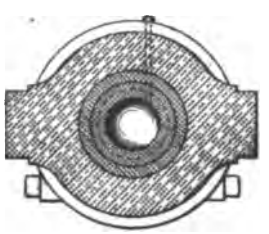


Fig. 4.

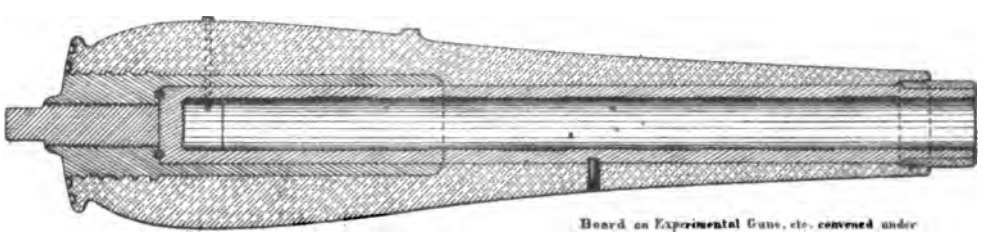
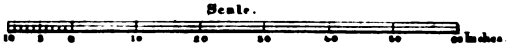


Fig. 2.

Scale.



Board on Experimental Guns, etc. convened under orders of the War Department dated October 10, 1874.

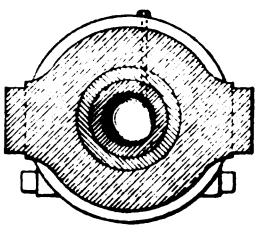
Geo W. McKee
Captain of Ordnance Recorder.

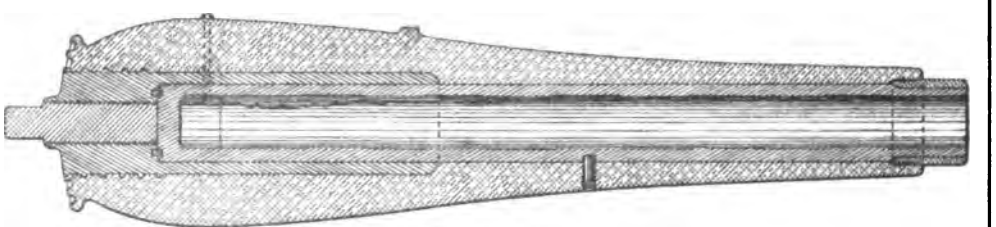
Plate. I.

Plate. I.

10 INCH RODMAN S.B. GUN CONVERTED INTO AN 8 INCH M.L RIFLE:

by lining with a jacketed steel tube inserted through the breech.





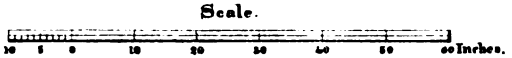
NOTE

This Sketch shows the condition of the tube after the 175th round.

Board on Experimental Guns, etc. convened under orders of the War Department, dated October 10 1874.

Geo W. McKee
Captain of Ordnance Recorder.

Scale.



10 INCH RODMAN S.B. GUN CONVERTED INTO AN 8 INCH M.L. RIFLE:

by lining with a jacketed steel tube inserted through the breech.

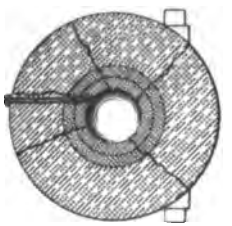


Fig. 3.

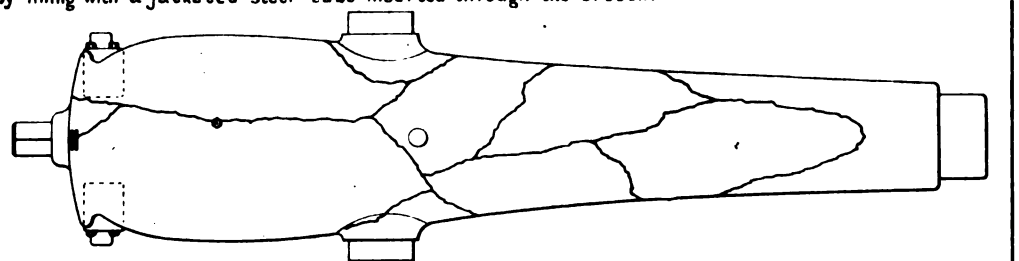


Fig. 1.

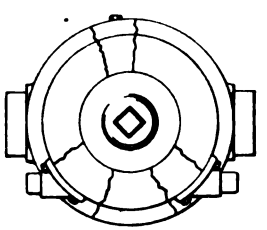


Fig. 4.

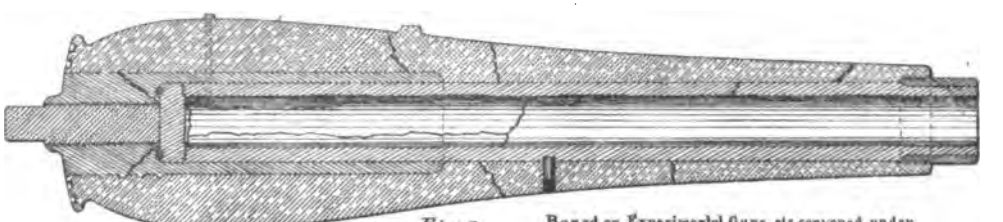


Fig. 2.

Board on Experimental Guns, etc convened under orders of the War Department, dated October 10, 1874.

Geo. W. McKee
Captain of Ordnance, Recorder.

Scale.

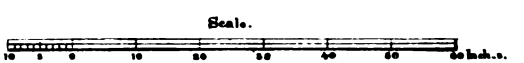
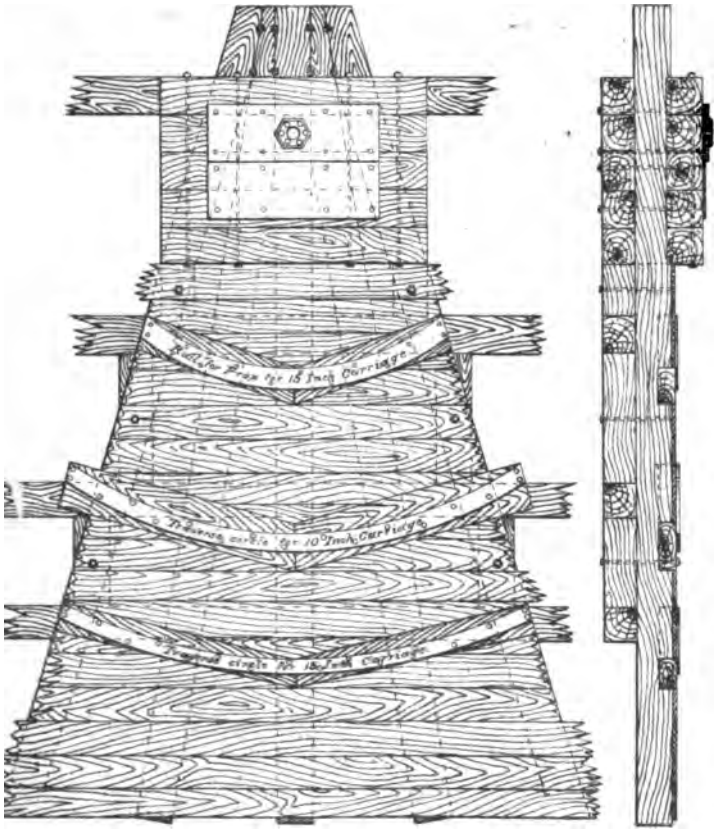


Plate. I.

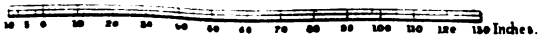
PLATFORM FOR AN 8 INCH CONVERTED RIFLE.



Board on Experimental Guns, etc. convened under orders of the War Department dated October 10. 1874.

Geo. W. McKee
Captain of Ordnance Recorder.

Scale.



APPENDIX L.

Trial of the eight-inch converted rifle No. 5.

OFFICE OF THE ORDNANCE BOARD, U. S. A.,
New York City, October 18, 1876.

SIR: I have the honor to transmit herewith the report of the Ordnance Board of the trial of the 8-inch converted rifle No. 5, accompanied by the recommendations of the Board.

Very respectfully, your obedient servant,

S. CRISPIN,
Brevet Colonel U. S. A., Lieutenant-Colonel of Ordnance,
President of the Board.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

DESCRIPTION OF GUN.

The gun is identical in its construction, and dimensions of tube and cast-iron casing, with 8-inch gun No. 1, given in report of Board on Experimental Guns, &c., to the Chief of Ordnance, dated January 9, 1875, with the exception that the tube is of American manufacture, being constructed by the Messrs. Paulding, Kemble & Co., at the West Point foundry, Cold Spring, N. Y.

CARRIAGE, POWDER, AND PROJECTILES.

The carriage, powder, and projectiles were in all essential particulars the same as those used in the trial of the 8-inch gun No. 1.

For details of firing, enlargements, &c., see accompanying tables Nos. 1, 2, 3, and 4.

CONCLUSIONS.

The gun remains in a sound and serviceable condition after its proof, and the star-gaugings and gutta-percha impressions, taken from time to time during the trial, show that the enlargements and the effects of erosion are not sensibly different from those observed in gun No. 1; the Board therefore concludes that tubes of American manufacture are suitable for use in the converting of 10-inch smooth-bores into 8-inch rifles.

S. CRISPIN,
Brevet Colonel U. S. A., Lieutenant-Colonel of Ordnance,
President of the Board.
T. J. TREADWELL,
Major of Ordnance.
T. G. BAYLOR,
Major of Ordnance.
GEO. W. McKEE,
Captain of Ordnance, Recorder.

TABLE No. 1.—*Record of firings for endurance with the 8-inch experimental rifle No. 5, from July 15 to October 11, (inclusive,) 1876, at Sandy Hook, N. J.*

Description of gun.—A rifle converted from a 10-inch Rodman cast-iron smooth-bore, by lining with a jacketed wrought-iron coiled tube inserted at the muzzle; caliber, 8 inches; total length of gun, 136.66 inches; length of bore, 117.25 inches; length of rifling, 107.25 inches; diameter of bore, including grooves, 8.15 inches; number of grooves and lands, 15 each; twist, uniform, one turn in 40 feet; weight of gun, 16,000 pounds.

Date.	Number of shots.	Charge.				Projectile.				Mean observed velocity of projectile at 110 feet from the muzzle of the gun, as recorded with the Le Boulengé chronograph.	Velocities at the muzzle.	Energy of projectile.		Gas pressure per square inch of surface of bore, as taken with Rodman's internal-pressure gauge.	Recoil of upper carriage.
		Kind of powder.	Cartridge.									Total at muzzle. $\frac{WV^2}{2g}$	Per inch of shot's circumference. $\frac{WV^2}{2g\,2\pi R}$		
			Weight.	Height.	Diameter.	Kind.	Weight.	Length.	Diameter.						
			Pounds.	*Inches.*	*Inches.*		*Pounds.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*	*Ft. lbs.*	*Ft. lbs.*	*Pounds.*	*Feet.*
August 18, 23, 28, and 29, September 7, 11, and 27, October 3, 5, 6, 7, 10, and 11.	237	Du Pont's hexagonal, F. U. E. V.	35	22	7.15	Butler ..	180	19	7.95	1,292	1,299	4,655,547	185,237	28,069	3.13
July 15, September 17 and 18, August 18, and October 5, and 7.	90	....do	35	22	7.15	..do	169	18	7.95	1,349	1,357	4,836,879	192,453	19,087	2.89
August 29	14	....do	35	22	7.15	Arrick ..	165	19	7.95	1,224	1,231	3,886,145	154,625	21,825	2.96
August 29	25	....do	35	22	7.15	..do	180	19	7.95	1,257	1,262	4,455,641	177,284	24,800	3.26
July 28, August 28 and 29	18	....do	35	22	7.15	Dana ...	165	19	7.95	1,413	1,421	5,178,345	206,039	33,500	2.95
August 29	2	....do	35	22	7.15	..do	180	19	7.95	1,197	1,203	4,048,765	161,091	20,000	2.88
July 26, 27, and 28	15	Du Pont's hexagonal, G. I. E. V.	35	22	7.15	Butler ..	170	18	7.95	1,447	1,457	5,609,008	223,175	27,607	3.75
July 26, 27, and 28	72	....do	35	22	7.15	..do	177	19	7.95	1,416	1,425	5,586,271	222,270	29,517	3.78
July 28	17	....do	35	22	7.15	Arrick ..	165	19	7.95	1,402	1,411	5,105,717	203,149	39,000	3.28
[illegible]	5	....do	35	22	7.15	..do	180	19	7.95	1,416	1,424	5,672,982	225,729	36,000	3.35
[illegible]	[illegible]	[illegible]	35	22	7.15	Dana ...	165	19	7.95	.....	.....	.....	.....	.....	3.00
[illegible]	[illegible]	[illegible]	[illegible]	22	7.15	Butler ..	181	19	7.95	1,411	1,419	5,664,509	225,383	36,750	3.96

September 27	2	Hazard's cubical, A.	35	22	7.15	..do	411										
	500																

Remarks.—Distance of the first wire target from muzzle of the gun, 60 feet; distance between first and second targets, 100 feet; mean weight of projectiles, using battering-charges, (35 pounds,) 175.74 pounds; mean velocity at muzzle, using battering-charges, (35 pounds,) 1,340 feet; mean maximum pressure, using battering-charges, (35 pounds,) 27,019; mean energy at the muzzle, using battering-charges, (35 pounds,) 4,868,125; maximum velocity at muzzle, obtained with 35 pounds of powder and 165 pounds projectile, 1,421 feet. Maximum velocity at muzzle, with 35 pounds of powder and 170 pounds projectile, 1,457; maximum velocity at muzzle, with 35 pounds of powder and 180 pounds projectile, 1,424 feet. Mean recoil of upper carriage, 3.23. Butt, 200 feet from muzzle of gun.

Four hundred and seventy-one shots were fired into butt 200 feet from the muzzle of the gun. Twenty into a target 20 × 40 feet at a distance of one mile from the gun, and 9 others as sighting-shots at mile target. Large share of tables worked by Mr. H. A. Sinclair.

TABLE No. 2.—*Record of firings with the 8-inch experimental rifle No. 5, July 15, 1876, at Sandy Hook, N. J.*

Description of gun.—A rifle converted from a 10-inch Rodman cast-iron smooth-bore by lining with [redacted] a jacketed wrought-iron coiled tube inserted from the front or muzzle; caliber, 8 inches; total length [redacted] of gun, 136.66 inches; length of bore, 117.25 inches; length of rifling, 107.25 inches; diameter of bo[redacted]re, including groove, 8.15 inches; number of grooves and lands, 15 each; twist uniform, one turn in 40 feer [redacted]t; weight of gun, 16,000 pounds.

Date.	Number of fire.	Charge.				Projectile.				Velocities.	Maximum pressure per square inch at surface of bore.	Recoil upper carriage.	[redacted]
		Kind of powder.	Cartridge.			Kind.	[redacted]	Length.	Diameter.				
			Weight.	Height.	Diameter.								
			Lbs.	*In.*	*In.*		*Lbs.*	*In.*	*In.*	*Feet.*	*Lbs.*	*Fe*[redacted]*et.*	
July 15, 1876	1	DuPont's hexagonal, F. U. E. V.	20	12.5	7.15	Butler	163	18	7.95	Lost ..	5,000	1.[redacted]	50
July 15, 1876	2		20	12.5	7.15	Butler.	163	18	7.95	1,082	7,500	2.[redacted]	25
July 15, 1876	3		25	15.6	7.15	Butler.	167	18	7.95	1,210	8,000	2.[redacted]	25
July 15, 1876	4		25	15.6	7.15	Butler.	171	18	7.95	1,230	13,500	2.[redacted]	08
July 15, 1876	5		25	15.6	7.15	Butler.	171	18	7.95	1,196	13,500	1.	84
July 15, 1876	6		30	19.7	7.15	Butler.	168	18	7.95	1,290	16,000	2.	08
July 15, 1876	7		30	19.7	7.15	Butler.	168	18	7.95	1,284	16,500	2.	25
July 15, 1876	8		30	19.7	7.15	Butler.	168	18	7.95	1,283	17,500	2.	25
July 15, 1876	9		30	19.7	7.15	Butler.	168	18	7.95	1,291	15,000	2.	17

Remarks.—Distance from muzzle of gun to first wire target, 60 feet; distance between targets, [redacted] 00 feet; distance from muzzle of gun to butt, 200 feet. All of these shots were fired into the butt, [redacted]d were preliminary to the rounds fired afterward to test the endurance of the gun.

: No. 3.—*Relative diameters of bore of cast-iron body of* 10-*inch gun and of wrought-tube* (*American manufacture*) *for insertion therein at different points of their cylindri-length.*

Interior diameters of bore.	Exterior diameters of tube.	Inches from face of muzzle.	Interior diameters of bore.	Exterior diameters of tube.	Inches from face of muzzle.	Interior diameters of bore.	Exterior diameters of tube.
13.500	13.495	91	13.500	13.495	50	13.500	13.495
13.500	13.495	90	13.500	13.495	48	13.500	13.495
13.498	13.495	89	13.500	13.495	46	13.501	13.495
13.499	13.495	88	13.500	13.495	44	13.500	13.495
13.500	13.495	87	13.500	13.495	42	13.500	13.495
13.499	13.495	86	13.498	13.495	40	13.500	13.495
13.498	13.495	85	13.499	13.495	38	13.500	13.495
13.499	13.495	84	13.500	13.495	36	13.500	13.495
13.500	13.495	83	13.499	13.495	34	13.500	13.495
13.500	13.495	82	13.499	13.495	32	13.500	13.495
13.500	13.495	81	13.499	13.495	30	13.501	13.495
13.500	13.495	80	13.499	13.495	28	13.501	13.498
13.499	13.495	78	13.498	13.495	26	13.502	13.498
13.500	13.495	76	13.499	13.495	24	13.502	13.498
13.500	13.495	74	13.499	13.495	22	13.502	13.498
13.500	13.495	72	13.500	13.495	20	13.503	13.500
13.500	13.495	70	13.500	13.495	18	13.504	13.499
13.500	13.495	68	13.500	13.495	16	13.503	13.498
13.500	13.495	66	13.499	13.495	14	13.502	13.498
13.500	13.495	64	13.500	13.495	12	13.503	13.498
13.500	13.495	62	13.500	13.495	10	13.503	13.500
13.500	13.495	60	13.500	13.495	8	13.503	13.500
13.500	13.495	58	13.499	13.495	6	13.504	13.500
13.500	13.495	56	13.500	13.495	4	13.505	13.500
13.500	13.495	54	13.500	13.495	2	13.505	13.500
13.500	13.495	52	13.500	13.495	1	13.505	13.500

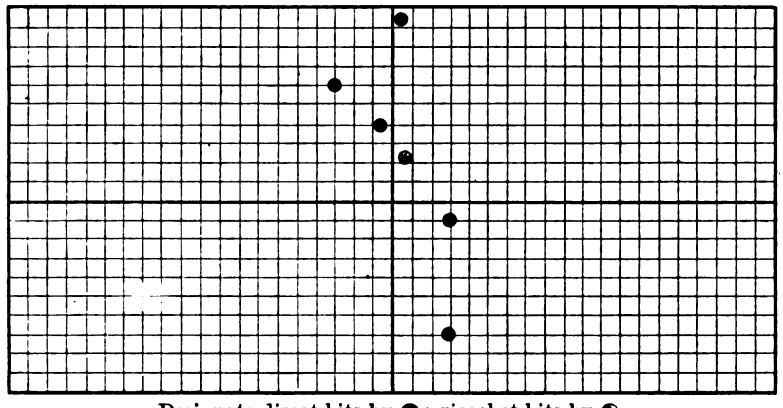
TABLE No. 4.—*Table of enlargements of 8-inch converted rifle No. 5.*

Inches from bottom of bore.	Original play of tube.	Original diameter of bore.	Enlargements after five charges of 20 to 30 pounds.	A.—Enlargement after 12 rounds, seven battering-charges.	Enlargement from column A, (after setting up of tube.)					Total enlargement after 509 rounds, including the setup of tube.
					After a total of 100 rounds.	After a total of 201 rounds.	After a total of 320 rounds.	After a total of 420 rounds.	After a total of 509 rounds.	
11	0.005	8.003	0.002	0.008	0.008	0.008	0.012	0.012	0.012	0.020
13	0.005	8.003	0.001	0.009	0.008	0.008	0.013	0.013	0.013	0.022
16	0.005	8.002	0.001	0.008	0.010	0.010	0.013	0.013	0.013	0.021
19	0.005	8.001	0.002	0.006	0.013	0.013	0.016	0.018	0.018	0.024
22	0.005	8.001	0.002	0.005	0.014	0.016	0.019	0.021	0.021	0.026
25	0.005	8.001	0.002	0.008	0.013	0.016	0.019	0.021	0.021	0.029
29	0.005	7.999	0.002	0.015	0.028	0.029	0.030	0.033	0.033	0.048
31	0.005	7.999	0.002	0.008	0.012	0.013	0.014	0.017	0.017	0.025
34	0.005	7.999	0.002	0.007	0.002	0.002	0.004	0.007	0.007	0.014
37	0.005	8.000	0.001	0.003	0.002	0.002	0.004	0.005	0.005	0.008
41	0.005	8.000	0.001	0.001	0.000	0.000	0.001	0.004	0.004	0.007
45	0.005	8.000	0.002	0.002	0.000	0.000	0.001	0.005	0.005	0.007
51	0.004	8.000	0.002	0.002	0.000	0.000	0.000	0.004	0.004	0.006
55	0.005	8.000	0.002	0.002	0.000	0.000	0.000	0.004	0.004	0.006
61	0.005	8.000	0.002	0.002	0.000	0.000	0.001	0.004	0.004	0.006
65	0.006	8.000	0.002	0.002	0.000	0.000	0.001	0.004	0.004	0.006
71	0.005	8.001	0.001	0.001	0.000	0.000	0.001	0.002	0.002	0.004
75	0.005	8.001	0.001	0.001	0.000	0.000	0.000	0.002	0.002	0.004
85	0.005	8.000	0.002	0.002	0.000	0.000	0.000	0.003	0.003	0.005
95	0.004	8.002	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002
105	0.005	8.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
117	0.005	8.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TARGET RECORD—CLASSES 1, 4, AND 5.

Date of report: September 11, 1876.
Where trials made: Sandy Hook, N. J.
By whom made: The Ordnance Board.
For what purpose: To show accuracy.
Range: 1,760 yards.

Target 40 feet by 20 feet.



Designate direct hits by ●; ricochet hits by ◐.

Gun: 8-inch experimental rifle, No. 5.
Projectile: Butler.

Number of hits, direct	5
Number of hits, ricochet	0
Number of misses	0
Total number of shots	5

Mean vertical deviation from center of impact	5.04
Mean horizontal deviation from center of impact	1.92
Mean deviation from center of impact	5.39

NOTE.—In obtaining center of impact direct hits only are counted.

EXPERIMENTS AND REPORTS WITH CANNON AND PROJECTILES—CLASSES 1, 4, AND 5.

Target record of firing with 8-inch experimental rifle No. 5 at Sandy Hook, N. J., September 11, 1876.

Number of fire.	Date.	Powder.		Projectile.		Elevation in degrees.		Recoil, feet.	Distance from center of target in feet.				Distance from center of impact in feet.				Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
		Kind.	Weight. Pounds.	Kind.	Weight. Pounds.				Vertical.		Horizontal.		Vertical.		Horizontal.		
									Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
						°	′										
276	Sept. 11	Dupont's Hexagonal, F. U. E. V.	35	Butler	180	3	0	3.83	9.50	.....	0.50	.....	7.20	.....	.....	0.10	Clear, smooth sound.
277	Sept. 11	....do	35	....do	180	2	55	3.17	4.00	.....	.....	0.50	1.70	.....	.....	1.10	Do.
278	Sept. 11	....do	35	....do	180	2	55	3.75	.....	1.00	3.00	.....	.....	3.30	2.40	.....	Do.
279	Sept. 11	....do	35	....do	180	2	55	3.08	.....	7.00	3.00	.....	.....	9.30	2.40	.....	Do.
280	Sept. 11	....do	35	....do	180	3	0	2.92	6.00	.....	.....	3.00	3.70	.....	.....	3.60	Do.
									19.50	8.00	6.50	3.50	12.60	12.60	4.80	4.80	
									11.50÷5=2.30		3.00÷5=0.60		25.20÷5=5.04		9.60÷5=1.92		

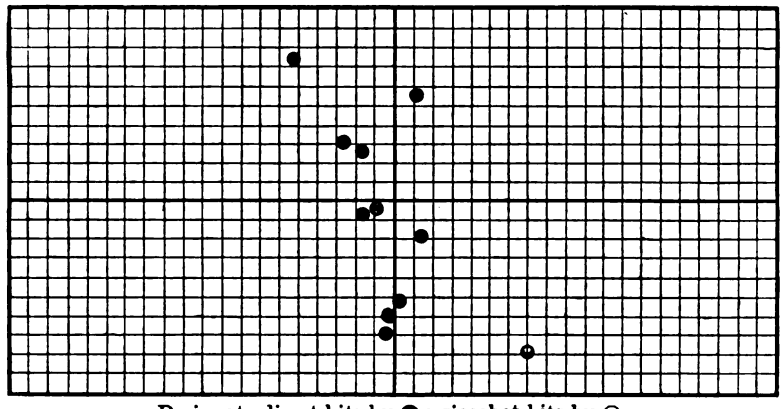
REMARKS.

Kind of cannon, number, and where made: 10-inch Rodman, S. B., (foundry No., 2266,) converted into an 8-inch rifle. Diameter of bore: 8 inches. Weight of piece: 16,000 pounds. Character of rifling: Twist uniform; one turn in 40 feet. Kind of carriage: 10-inch Rodman. Height of axis of bore above plane on which projectile strikes: 7 feet. By whom pointed: Col. T. G. Baylor.

TARGET RECORD—CLASSES 1, 4, AND 5.

Date of report: October 10, 1876.
Where trials made: Sandy Hook, N. J.
By whom made: The Ordnance Board.
For what purpose: To show accuracy.
Range: 1,760 yards.

Target 40 feet by 20 feet.



Designate direct hits by ●; ricochet hits by ◒.

Gun: 8-inch rifle, No. 5.
Projectile: Butler.

Number of hits, direct	9
Number of hits, ricochet	1
Number of misses	5
Total number of shots	15

Mean vertical deviation from center of impact	4.29
Mean horizontal deviation from center of impact	1.53
Mean deviation from center of impact	4.54

NOTE.—In obtaining center of impact direct hits only are counted.

EXPERIMENTS AND REPORTS WITH CANNON AND PROJECTILES—CLASSES 1, 4, AND 5.

Target record of firing with 8-inch experimental rifle No. 5 at Sandy Hook, N. J., October 10, 1876.

Number of fire.	Date.	Powder.		Projectile.		Elevation in degrees.	Recoil, feet.	Wind, strength and direction.	Hit.	Distance from center of target in feet.				Distance from center of impact in feet.				Remarks.
		Kind.	Weight.	Kind.	Weight.					Vertical.		Horizontal.		Vertical.		Horizontal.		
										Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
			Lbs.		Lbs.	° ′												
490	Oct. 10	Dupont's hexagonal, F. U. E. V.	35	Butler.	180	3 5	2.58	Right to left, 17 miles per hour.	Direct hit...	3.00	.....	.....	2.50	3.31	.....	.....	1.51	
491	Oct. 10	.....do.....	35	..do...	180	3 5	2.50		....do.....	7.08	.....	.....	5.08	7.40	.....	.....	4.09	
492	Oct. 10	.....do.....	35	..do...	180	3 5	4.57		....do.....	.....	2.00	1.25	.....	.....	1.68	2.24	.....	
493	Oct. 10	.....do.....	35	..do...	180	3 5	2.17		....do.....	5.42	.....	1.00	.....	5.73	.....	1.99	.....	
494	Oct. 10	.....do.....	35	..do...	180	3 5	2.33		....do.....	2.58	.....	.....	1.83	2.90	.....	.....	.....	
495	Oct. 10	.....do.....	35	..do...	180	3 5	4.08		Ricochet hit*	.....	8.00	7.00	.....	.....	.....	.....	.....	
496	Oct. 10	.....do.....	35	..do...	180	3 5	1.67		.....	.....	.....	.....	.....	.....	.....	.....	.....	Struck 124 paces front of target.
497	Oct. 10	.....do.....	35	..do...	180	3 10	3.65		.....	.....	.....	.....	.....	.....	.....	.....	.....	Under target.
498	Oct. 10	.....do.....	35	..do...	180	3 12½	2.00		Direct hit...	.....	6.92	.....	0.25	.....	6.61	0.74	.....	
499	Oct. 10	.....do.....	35	..do...	180	3 15	2.00		.....	.....	.....	.....	.....	.....	.....	.....	.....	Under target.
500	Oct. 10	.....do.....	35	..do...	180	3 17	3.71		Direct hit...	.....	0.67	.....	1.50	.....	0.35	.....	0.51	
501	Oct. 10	.....do.....	35	..do...	180	3 20	2.00		....do.....	.....	5.33	0.17	.....	.....	5.02	1.16	.....	
502	Oct. 10	.....do.....	35	..do...	180	3 22½	3.58		.....	.....	.....	.....	.....	.....	.....	.....	.....	Over target.
503	Oct. 10	.....do.....	35	..do...	180	3 20	2.00		Direct hit...	.....	6.00	.....	0.17	.....	5.68	0.82	.....	
504	Oct. 10	.....do.....	35	..do...	180	3 20	2.50		.....	.....	.....	.....	.....	.....	.....	.....	.....	Over target.
										18.08	20.92	2.42	11.33	19.34	19.34	6.95	6.95	
										2.84÷9=0.32		8.91÷9=0.99		38.68÷9=4.29		13.90÷9=1.53		

* Not included in calculating center of impact.

REMARKS.—Kind of cannon, number, and where made: 10-inch Rodman, S. B., (foundry No., 2266,) converted into an 8-inch rifle. Diameter of bore: 8 inches. Weight of piece: 16,000 pounds. Character of rifling: Twist uniform; one turn in 40 feet. Kind of carriage: 10-inch Rodman. Height of axis of bore above plane on which projectile strikes: 7 feet. By whom pointed: Mr. A. G. Sinclair.

APPENDIX M.

Trial of the new model five-barreled Gatling gun, cal. .45.

OFFICE OF THE ORDNANCE BOARD, U. S. A.,
New York City, September 25, 1876.

SIR: I have the honor to transmit herewith the report of the ordnance board on the trial of the new model five-barreled Gatling gun, 0″.45 caliber, at Sandy Hook, N. J., made in accordance with your letter of instructions of July 21, 1876.

Very respectfully, your obedient servant,

S. CRISPIN,
Brevet-Colonel U. S. A., Lieutenant-Colonel of Ordnance,
President of the Board.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

REPORT ON THE NEW MODEL FIVE-BARRELED GATLING GUN, CALIBER 0″.45.

In accordance with the instructions of the Chief of Ordnance of July 21, directing the ordnance board to make an examination, trial, and report of the new model five-barreled Gatling gun, presented for trial by the Gatling-Gun Company of Hartford, Conn., the board has the honor to submit the following report of trial and record of firing, made at Sandy Hook, N. J., August 16 to August 23, Dr. Gatling and Mr. Edgar T. Welles of the Gatling-Gun Company being present.

Two guns were submitted by the company for tests, one being a short five-barreled gun designed for cavalry service, the other a long ten-barreled gun for flank-defense.

The improvements in the gun intended for service with cavalry consist in a change of the position and attachment of the crank from the side to the rear, greatly facilitating and increasing the speed of revolution of the gun and rapidity of its fire; the feed-cases are entered more readily to the receiver, and stand vertically, thus insuring a direct fall and feed of the metallic cases; the exterior form of the receivers admits of reversing the motion of the crank without danger of jamming the cases. All the working parts as well as the barrels are encased in bronze, affording better protection from dust and dirt to the gun. It is lighter and of less expensive construction, and more compact in appearance. An automatic device attached to the breech of this gun gives a traversing motion through a small angle, which can be set to suit range and circumstances of fire, and is worked by the crank operating the gun. The increased rapidity of fire is seen, from an examination of the record, to be more than double that of the old model ten-barreled gun, and its accuracy is by no means impaired.

The board is of opinion that the application of the crank to the rear, vertical feed, automatic traversing motion, lightness, cheapness, &c., are all important improvements.

All the changes and improvements in the Gatling gun, for cavalry

service, are equally applicable to the long-barreled gun for flank-defense, as was shown by their application to one of the old model guns during the trial.

It will be observed, from the record of firing, that a number of the service copper cartridges, 14, were torn through by the extractor and failed to extract, and two of the Berdan failed to extract for the same reason. It is thought this difficulty for all kinds of ammunition may be overcome by making the extractor wider, so as to embrace a greater portion of the rim of the cartridge. Experiments should be made to test this point fully before deciding which is the best ammunition for the new model gun.

In the extended firing with the old model guns, recently made at Sandy Hook, and reported upon to the Bureau June 20, 1876, none of the extractors cut through any of the cases under trial, and the accident seems due to the greatly increased rapidity of fire, due to the improvements in the new model gun.

The records of the firing are herewith appended.

S. CRISPIN,
Brevet-Colonel U. S. A., Lieutenant-Colonel of Ordnance,
President of the Board.
T. J. TREADWELL,
Major of Ordnance.
T. G. BAYLOR,
Major of Ordnance.
GEO. W. McKEE,
Captain of Ordnance, Recorder.

Firing record, caliber .45-inch, new model five-barrel Gatling gun, at Sandy Hook, N. J., from August 16 *to August* 23, 1876.

Number of rounds.	Date.	Kind of ammunition.	Defects of shells.				Time of firing 1,000 rounds.	Number of rounds fired per minute.	Remarks.
			Split in body.	Heads pierced through with firing-pin.	Escape of gas at cap.	Rim of shells torn through by extractor.			
1,000	August 16	Bridgeport..	1	139	.....	1	2*m*. 35*s*.	.....	
1,000	August 16	Frankford ..	....	.....	.....	4	.....	.....	
1,000	August 16	Bridgeport..	....	61	100	.....	1*m*. 20*s*.	.....	
1,000	August 17	Bridgeport..	1	69	90	.....	.....	.....	Fired at 500-yard target.
1,000	August 18	Frankford ..	....	.....	.....	.....	1*m*. 28*s*.	.....	
1,000	August 18	Bridgeport..	....	65	42	1	1*m*. 55*s*.	680	
1,000	August 18	Lowell.....	3	.....	302	.....	.....	.....	
1,000	August 18	Winchester .	....	.....	889	.....	.....	760	
1,000	August 18	Frankford ..	....	.....	.....	4	.....	600	
1,000	August 18	Bridgeport..	....	71	163	.....	1*m*. 19*s*.	760	
1,000	August 18	Lowell.....	1	.....	157	.....	.....	600	
1,000	August 18	Frankford ..	....	.....	.....	6	.....	640	
1,000	August 18	Lowell.....	...	.....	.....	.....	1*m*. 20½*s*.	760	
1,000	August 23	Frankford ..	....	.....	.....	.....	.....	.....	Fired at 1,000-yard target.

GENERAL SUMMARY.

: 405 heads pierced through with firing-pin; 395 escape of gas at cap; 2 split in body; fired in 1 minute 47 seconds; average number fired per minute, 720. The rims of two by extractor.

escape of gas at cap; 4 split in body; 1,000 rounds fired in 1 minute 20¾ seconds; average per minute, 680.

: 889 heads pierced through with firing-pin; number fired per minute, 760.

14 rims torn through with extractor; 1,000 fired in 1 minute 28 seconds; average number ute, 620.

:ract from report of board on old-model Gatling gun, caliber .45 inch, June 20, 1876:

	Average number per minute.
ll	250
eport	216
hester	266
rford	222

d caliber .45 inch ten-barrel Gatling gun at Sandy Hook, N. J., from August 16 *to August* 18, 1876.

	Kind of ammunition.	Time of firing 1,000 rounds.	Time of firing one case forty rounds.	Torn asunder in body of shell.	Rim of shell torn through by extractor.	Remarks.
st 16	Bridgeport		2½*s.*			
st 16	Bridgeport		1¾*s.*			
st 16	Bridgeport		1¾*s.*			
st 16	Bridgeport	1*m.* 29¼*s.*				
st 17	Bridgeport			2		Fired at 500-yard target.
st 17	Bridgeport					
st 17	Frankford				4	
st 17	Lowell					
st 18	Bridgeport		1½*s.*			
st 18	Bridgeport		1½*s.*			
st 18	Bridgeport		1½*s.*			
st 18	Bridgeport		1½*s.*			
st 18	Bridgeport		1½*s.*			

GENERAL SUMMARY.

1,000 rounds fired in 1 minute and 29¼ seconds. Average time of firing one case of 40 onds. Two cases torn asunder in body of shell.

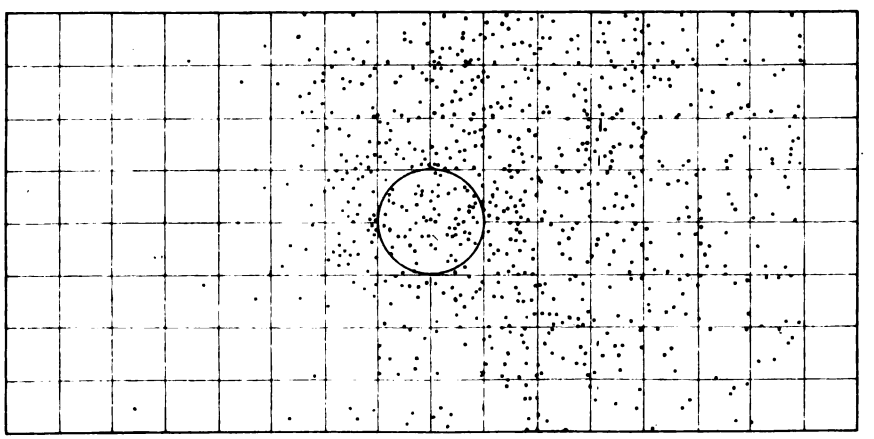
Four rims torn through by extractor.

Target Record 5 barrel new model Gatling gun.

500 Yards Aug. 16th 1876.

at Sandy Hook N.Y.H.

Nº of Shots fired deliberately 1000 Nº of hits 782.



George W. McKee
Capt. of Ordnance
Recorder of Ordnance Board.

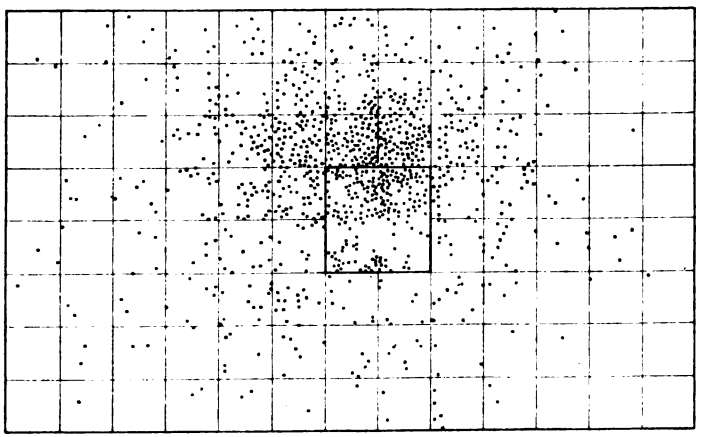
Target No. ...

Target Record 10 barrel Gatling gun.

500 Yards, Aug. 17th 1876.

at Sandy Hook, N.Y.H.

No. of shots fired deliberately 1000. No. of hits...996.



Target, 13 feet long, 8 feet wide.

George W. McKee
Capt of Ordnance
Recorder Ordnance Board.

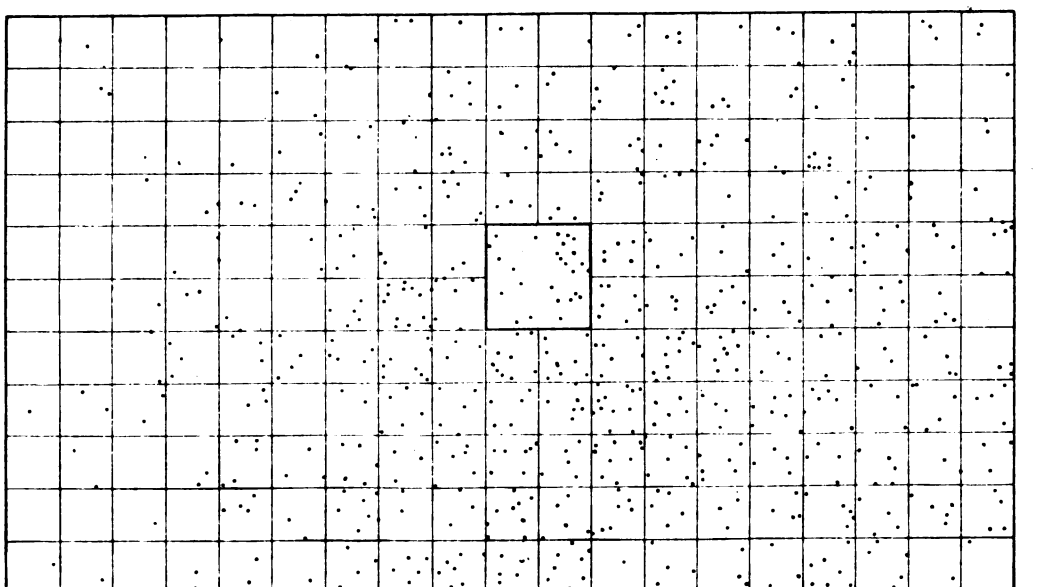
Target Record 5 barrel new model Gatling gun.

1000 Yards. Aug. 23d 1876.

at Sandy Hook, N.Y.H.

Nº of Shots fired deliberately 1000

Nº of hits . . 665 .



Target 19 feet long, 11 feet wide.

George W. McKee
Capt Of Ordnance
Recorder of Ordnance Board

CAP

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APPENDIX N.

Woodbridge gun.

PERIODICAL REPORTS ON THE CONSTRUCTION OF THE EXPERIMENTAL 10-INCH WOODBRIDGE MUZZLE-LOADING RIFLED GUN, MADE BY OFFICERS OF THE ORDNANCE DEPARTMENT STATIONED AT FRANKFORD ARSENAL TO THE COMMANDING OFFICER THEREOF, MAJOR T. J. TREADWELL.

CAPT. WILLIAM PRINCE'S FIRST REPORT, MARCH 31, 1875.

This being the first report upon the construction of the Woodbridge gun, it seems desirable, in order to render it and subsequent reports intelligible, that a short *résumé* of the history of the system should be furnished, bringing the whole subject up to date.

And first as to the—

WOODBRIDGE SYSTEM.

The Woodbridge gun consists of a thin steel barrel, strengthened by wire wound on its exterior surface, barrel and wire being subsequently consolidated into one mass by a brazing solder melted into the interstices. It is well described in a single paragraph extracted nearly verbatim from a letter of Dr. Woodbridge to the Chief of Ordnance, August 5, 1861:

"Square wire is wound upon a steel core somewhat larger than the intended bore of the gun, a sufficient number of wires being wound at once, side by side, to produce the required obliquity of the turns. The successive layers have opposite twist, their number being, of course, sufficient to give the desired exterior diameter to the gun. When thus wound the whole mass is inclosed in a tight case, to protect it from oxidation, and is heated therein to a temperature somewhat above that required for the fusion of the metal to be used for consolidating it. The soldering metal is then run in, filling all the interstices of the mass. When properly cooled the gun is bored and finished from the mass in much the same way as if it were a common casting."

HISTORY OF THE SYSTEM.

The first official cognizance of the system by the Ordnance Department of the Army appears to date from—

August 5, 1850.—Letter of Dr. Woodbridge of July 30, 1850, addressed to General Scott, Acting Secretary of War, asking trial of his system and inclosing description, referred to the Chief of Ordnance.—(Report of Chief of Ordnance 1872, p. 159.)

August 5, 1861.—Dr. Woodbridge addressed General Ripley, Chief of Ordnance, presenting anew his plan.—(Report of Chief of Ordnance 1872, p. 161.)

December 24, 1864.—Dr. Woodbridge, through his attorney, F. B. Van Vleck, of New York, addressed General Dyer, Chief of Ordnance, presenting his plan again, with tables, &c.—(Report of Chief of Ordnance 1872, p. 161.)

In response to this letter Dr. Woodbridge was apparently requested to furnish full particulars of his method; for—

February 1, 1865.—Dr. Woodbridge addressed General Dyer, Chief of Ordnance, giving estimates and full description of mode of fabricating his guns, with drawings of guns and detail.—(Report of Chief of Ordnance 1872, p. 164.)

The subject was apparently referred to the commanding officer of the National Armory for trial of small model; for—

July 15, 1865.—Major Laidley, commanding National Armory, makes report on the trial of a 2½-inch model Woodbridge gun, fired 1,327 rounds, "strength and endurance abundantly demonstrated."—(Report of Chief of Ordnance 1872, p. 170.)

At this stage the matter seems to have rested, probably for want of appropriations to further test the value of the system; but—

June 6, 1872.—An act is approved appropriating $270,000 for tests of heavy rifled ordnance of at least three models, including breech and muzzle loaders.—(Report of Chief of Ordnance 1872, p. 16.)

June 28, 1872.—A board (Colonel Whiteley, president) is ordered (General Orders, Adjutant-General's Office, No. 57, 1872) to select and designate models for experiments under the act of June 6, 1872.—(Report of Chief of Ordnance 1872, p. 16.)

July 16, 1872.—Dr. Woodbridge presented to the board of June 28 a general description of his plan for construction of large guns as proposed.—(Report of Chief of Ordnance 1872, p. 167.)

July 25, 1872.—Dr. Woodbridge, by request, presents to the board of June 28 estimates of cost of construction of 12-inch and 9-inch guns on his plan, as follows: 12-inch rifled gun, $32,474; 9-inch rifled gun, (independently,) $15,130; 9-inch rifled gun, if made in conjunction with 12-inch gun, $7,975.—(Report of Chief of Ordnance 1872, p. 172.)

September 18, 1872.—Report of board of June 28 approved by the Chief of Ordnance and Secretary of War, recommending "the plan of constructing heavy ordnance proposed by Dr. W. E. Woodbridge, of Little Falls, N. Y., as one of the systems for experiments and tests, under the provisions of the act of June 6, 1872, and that the gun be fabricated according to designs and specifications approved by the War Department." The report also designates the Woodbridge gun as the *first* in order among muzzle-loaders, in the contingency of discrimination being necessitated by limited appropriations.—(Report of Chief of Ordnance 1872, pp. 25, 30, and 31.)

A board (Lieutenant-Colonel Laidley, president) ordered by the Chief of Ordnance to fix the place and details of construction of the guns recommended by the board of June 28.—(Report of Chief of Ordnance 1872, p. 174.)

October 16, 1872.—Report of board of September 18 approved by the Secretary of War, recommending form and dimensions (with drawings) of 9-inch and 12-inch Woodbridge guns, and that they be made at Frankford Arsenal; all details to be intrusted to Dr. Woodbridge, the commanding officer of Frankford Arsenal to furnish all labor, materials, &c., and to "keep a record which shall furnish a complete history of the details of the construction of these guns."—(Report of Chief of Ordnance 1872, pp. 176 and 179; drawings appended, p. 180.)

October 18, 1872.—Commanding officer of Frankford Arsenal officially notified by letter of Chief of Ordnance that his arsenal has been selected for the fabrication of the Woodbridge gun; directed to consult Dr. Woodbridge's views, and to furnish all facilities, &c., and to keep a "*complete and minute record* of manufacture and experiments with materials of the gun, to be reported to the Chief of Ordnance on completion."

November 5, 1872.—Dr. Woodbridge advises the commanding officer

of Frankford Arsenal that he has ordered wire from Cooper, Hewitt & Co., (Trenton Iron Company,) to be proved at Washington navy-yard. Requests authority to visit Reading and Pittsburgh to inspect lathes.

November 8, 1872.—Dr. Woodbridge to visit Reading and Pittsburgh as above.

November 25, 1872.—Steel tube for 9-inch gun ordered from Naylor & Co., of New York, as follows: Length of tube, 15 feet; length of bore, 12½ feet; diameter, exterior, 13 inches; diameter of bore, 7½ inches; yielding strain, > 12 tons; breaking strain, > 30 tons; elongation, < 20 per cent.

November 26, 1872.—Naylor & Co., of New York, advise that they have transmitted the order for the 9-inch gun tube to their Sheffield house, Vickers' Sons & Co.

December, 1872.—Alterations commenced at rolling-mill for the purpose of adapting its eastern end to the construction of the Woodbridge gun.

December 6, 1872.—Naylor & Co., of New York, authorized to substitute the dimensions given in Dr. Woodbridge's letter to them of December 4 for those given in letter of commanding officer Frankford Arsenal November 25, (*v. supra.*) (No copy of this letter of Dr. Woodbridge is on file at Frankford Arsenal, but from letter of February 19, 1873, from commanding officer Frankford Arsenal to Naylor & Co., *q. v.*, it is inferred that the length of tube was changed from 15 feet to 15 feet 9 inches, and the length of bore from 12 feet 6 inches to 12 feet 7½ inches.

December 10, 1872.—Naylor & Co. acknowledge receipt of last, and request that Woolwich tests be accepted in the matter of proof-strains, &c.

Naylor & Co. advised that Woolwich tests will be accepted.

December 14, 1872.—Procurement of use of lathe at Washington navy-yard recommended, and that it be altered as suggested by Dr. Woodbridge.

January, 1873.—Alterations continued at rolling-mill. Water-supply provided and pipes laid.

January 6, 1873.—Phœnix Iron Company furnish prices for iron columns and beams required for supporting furnaces, &c.

January 13, 1873.—Colt's Fire-Arms Company of Hartford, Conn., requested to furnish prices of largest Baxter engines.

Major Crispin, New York, requested to furnish current quotations for copper and tin in that city.

January 14 *and* 15, 1873.—Iron columns for furnaces, &c., ordered from Phœnix Iron Company.

January 15, 1873.—Major Crispin quotes current New York prices. Copper 35½ cents; Banca tin 37 cents. States that 44,000 pounds of lake copper are in possession of the Department at New York and 13,000 pounds of Banca tin at Watervliet Arsenal.

January 16, 1873.—Dr. Woodbridge notified that the Navy Department will sell the lathe inspected by him at Washington navy-yard for $5,000, and estimate alterations at $3,000. Remarks solicited to facilitate report.

January 18, 1873.—Colt's Fire-Arms Company of Hartford receive order for a 10 horse-power Baxter engine with 15 horse-power boiler.

January 20, 1873.—Dr. Woodbridge approves the price and recommends the purchase of the lathe from the Navy Department.

January 23, 1873.—Purchase of the lathe at Washington navy-yard

requested, and that Dr. Woodbridge superintend its alteration at Washington.

January 30, 1873.—Notification received that the lathe has been purchased and will be altered at Washington under Dr. Woodbridge's supervision.

January 28 *and February* 1, 1873.—Dr. Woodbridge furnishes particulars as to foundation for lathe.

February, 1873.—Alterations at rolling-mill progress; foundations for furnaces, heating-case, and lathe commenced.

February 7, 1873.—Tracings of 9-inch and 12-inch Woodbridge guns received from Ordnance Office and directed to be modified to correspond with the center of gravity as last determined.

February 19, 1873.—Naylor & Co. informed, in answer to letter of inquiry of February 18, that the modified tube for the 9-inch gun is to be 15 feet 9 inches long and bored 12 feet 7½ inches.

March, 1873.—Work on foundations and furnaces continued; work on reel-carriage commenced.

March 11, 1873.—Corrected tracings of 9-inch and 12-inch guns received from Ordnance Office and ordered to be adhered to. The 9-inch designated as an "experimental block."

March 17, 1873.—Gun-case and heating-case for 9-inch gun ordered from Henry G. Morris, (Southwark foundry;) manufacture to be subject to inspection.

March 21, 1873.—Dr. Woodbridge requests some special fire-brick to be sent to him at Washington; incloses prices of copper and tin, "previously mentioned," (no previous mention on file,) obtained at Southwark foundry, (inclosure missing.) States that gun-tube from Firth & Sons, England, will be ready about "two weeks from February 28," as he learns from Abbott & Howard.

March 22, 24, *and* 27, 1873.—Correspondence about fire-brick and clay with firms in Philadelphia and Trenton, and with Dr. Woodbridge.

March 29, 1873.—Board (Lieutenant-Colonel Laidley, president) ordered (order of Chief of Ordnance) "to determine and report on the best method of rifling and venting the heavy guns now being made," &c.—(Report of Chief of Ordnance 1873, p. 25.)

April, 1873.—Erection of furnaces and fixtures progressing; reel-carriage in course of construction; brass reels rejected in favor of cast-iron ones; 12-inch-gun tube received from England.

April 7, 1873.—Dr. Woodbridge incloses bill of Trenton Iron Company for test-wire; suggests purchase of 500 to 1,000 pounds of the best kind produced by two makers to test uniformity; states that pump for "hydraulic lift" has been turned over by the Treasury Department "free of expense."

April 14, 1873.—Major Crispin advises that he has shipped the tube for Woodbridge gun (12-inch) from New York.

April 28, 1873.—Dr. Woodbridge requested to forward bill for steel tube (for 12-inch gun) for payment.

April 30, 1873.—Dr. Woodbridge states that Abbott & Howard expect the tube to be tested before payment, and requests specimen for test, giving dimensions.

May, 1873.—Work continued on alterations, furnaces, fixtures, and reel-carriage; 9-inch-gun tube received from England.

May 2, 1873.—Dr. Woodbridge advised that specimens will be furnished him from the 12-inch-gun tube as requested.

May 12, 1873.—Naylor & Co. telegraph arrival of 9-inch-gun tube from England, and request instructions.

Major Crispin requested to receive the tube and ship it to Henry G. rris, Southwark foundry; Naylor & Co. advised.

May 14, 1873.—Dr. Woodbridge states that tests of specimens from inch gun are satisfactory, and incloses bill of Abbott & Howard inrsed.

May 15, 1873.—Dr. Woodbridge advised that Morris, Tasker & Co. nnot make bore-extension tube till after July, and recommended to ve it made at Southwark foundry, where the heating-case, &c., are in urse of construction.

Naylor & Co. send invoice of 9-inch-gun tube.

May 16, 1873.—Dr. Woodbridge advised of result of inspection of nch tube, resulting as follows: Length of tube, 15′ 9″; length of bore, ′ 7½″; diameter of tube, (external,) 13⅛″; diameter of bore, 7⅜″; (8-inch ng afterward cut off of muzzle, shortening the tube probably 1 inch.)

May 19, 1873.—Naylor & Co. furnish report of English tests of 9-inchin tube, as follows: Yielding-strain, > 11½ tons; breaking-strain, 28½ tons; elongation, < 10 per cent.; bending cold after hardening, o.

May 25, 1873.—Report of board of March 29 on rifling and venting perimental guns approved by Chief of Ordnance.—(Report of Chief of dnance 1873, p. 32.)

May 29, 1873.—Double-spindle drill requested to be sent from National mory, to be used in splicing wire for Woodbridge gun.

May 29 *and June* 2, 1873.—Henry G. Morris (Southwark foundry) and debotham & Powell furnish, by request, estimates for iron chimneyack; both bids substantially the same, $740.

June and July, 1873.—Alterations at rolling-mill, furnaces, reel-carage, and fixtures in progress; water-bolts inserted in furnaces, &c.; ire-splicing machines erected.

July 19, 1873.—Phœnix Iron Company, in reply to inquiries, state that lumns will be ready in ten days and beams in three weeks.

July 28, 1873.—Henry G. Morris (Southwark foundry) advises that the inch-gun appurtenances (heating-case, gun-case, &c.,) are ready for inection.

August, 1873.—Alterations, furnaces, reel-carriage, and fixtures in ogress. Gun-case and heating-case for 9-inch gun received from uthwark foundry. Boring-tools and rests purchased in Pittsburgh.

August 20, 1873.—Southwark foundry (Henry G. Morris) furnished, by quest, with full details of flanges for 12-inch-gun tube.

August 29, 1873.—Iron City Works (Mackintosh & Hemphill) offer rtain boring-tools and rests for large-gun turning, &c., at low prices, by sight. Dr. Woodbridge selects and purchases certain of them by inrsement.

September and October, 1873.—Work continued on furnaces and fixres, reeling-machinery, wire-splicing machinery, and the heating-case r 9-inch gun.

October 6, 1873.—Heating-case and gun-case for 12-inch gun ordered m Henry G. Morris, (Southwark foundry.)

October 8, 1873.—The Chief of Ordnance requested to have the copr and tin at New York and Watervliet Arsenals (*vide* January 15, 73) sent to Frankford Arsenal for use in the manufacture of Woodidge guns, which will require 70,000 pounds of copper and 15,000 unds of tin.

November, 1873.—Work continued on furnaces, fixtures, and heatingse for 9-inch gun.

November 13, 17, 20, *and* 28, 1873.—Dr. Woodbridge informed of size

of beams ordered for the "hydraulic lift." Requests instructions as to shipping lathe from Washington. Is informed that the lathe has been turned over to the Quartermaster's Department for transportation. Authorized to visit Trenton and Washington.

November 18, 1873.—Beams for "hydraulic lift" ordered from Phœnix Iron Company.

December, 1873.—Work continued on furnaces, fixtures, and heating-case for 9-inch gun.

December 9, 12, 17, *and* 19, 1873.—Dr. Woodbridge informed that tin, copper, and fire-brick have been shipped to him at Washington, for tests, as requested. Acknowledged receipt in Washington of articles for test; refers to delay in forwarding lathe. Authorized to visit Trenton and Washington. Desires Mr. Gill in Washington to assist in taking down lathe. Mr. Gill ordered to Washington.

January, 1874.—Furnaces substantially completed. Work continued on fixtures and heating-case for 9-inch gun. Forty-eight thousand pounds coke for furnaces purchased in Pittsburgh.

January 3 *and* 24, 1874.—Dr. Woodbridge to visit Trenton, Pittsburgh, and Washington.

January 12, 1874.—Dr. Woodbridge reports results of his visit to Pittsburgh about wire. Firm doubtful about producing it, but going to try. Furnishes cost of coke, freight, &c.

February, 1874.—Work continued on general fixtures and heating-case for 9-inch gun. Foundation of lathe completed, and work on "hydraulic lift" commenced.

February 3 *and* 25, 1874.—Dr. Woodbridge to visit Trenton, Washington, Pittsburgh, Philadelphia, New York, and Boston about wire, &c.

February 16 *and* 18, 1874.—Henry G. Morris (Southwark foundry) reports 12-inch-gun case ready for inspection. Informed that an inspector will call. Receives order for iron box and conductor.

March, 1874.—Work continued on general fixtures, lathe, "hydraulic lift," and heating-case for 9-inch gun.

March 7 *and* 24, 1874.—Dr. Woodbridge authorized to visit Washington and Trenton about wire, &c.

April, 1874.—Work continued on general fixtures, lathe, winding apparatus, "hydraulic lift," and heating-case for 9-inch gun.

April 18 *and* 21, 1874.—Dr. Woodbridge authorized to visit Washington and Trenton about wire.

May, 1874.—Work continued on general fixtures, "hydraulic lift," and lathe. Melting-furnace fired up for trial; steel rods for wire contracted for.

May 9, 1874.—New Jersey Steel and Iron Company receive an order for 30,000 pounds steel rods at 12 cents per pound, to be $\frac{3}{8}''$ square, and to stand the following tests when drawn into wire .3″ square, (weights to be applied to a torsion lever-arm of one foot in length:) With 15 pounds the wire not to twist more than 3°.6 to 1 inch; with 50 pounds the wire not to break, (in 1 inch of length;) with 50 to 55 pounds, the wire, if broken, twist to be >.7 revolutions per inch; with 55 to 60 pounds, the wire, if broken, twist to be >.65 revolutions per inch; with 60 pounds +, the wire, if broken, twist to be >.6 revolutions per inch.

May 19, 1874.—The melting-furnace was fired up for trial in presence of Dr. Woodbridge.

May 21, 1874.—Dr. Woodbridge authorized to visit Washington and Trenton about wire.

June, 1874.—Work continued on general fixtures, lathe, and "hydraulic lift." Bronze melted in melting-furnace and cast into ingots.

ontracts entered into for labor and material to utilize unexpended ap-
ropriation for the fiscal year about to expire.

June 9, 19, *and* 26, 1874.—Dr. Woodbridge authorized to visit Tren-
on and Washington about wire, &c.

June 19, 1874.—Melting-furnace fired up, and about 8,000 pounds of
ronze (copper 5, tin 1) were melted and cast into ingots.

June 22, 1874.—Dr. Woodbridge advised by letter to come on, and
sked if he intends to go on with the 9-inch gun.

June 24, 1874.—Dr. Woodbridge writes that he will adhere to the orig-
al plan of making a 9-inch block and a 12-inch gun.

June 29, 1874.—Dr. Woodbridge furnished with full instructions as to
ow the work of making his guns will be carried on at Frankford Ar-
nal.

Trenton Iron Company receive an order like that of May 9 for 100,000
ounds of steel bars and drawing to .3 inch, and annealing, the latter
erations not to increase the cost of the bars (12 cents) by more than
cents per pound.

B. Rowland, jr., & Bro., Frankford, receive an order for 160 tons of
al for Woodbridge gun-works.

P. Neukumet receives an order for 200 barrels of fire-clay, ground fire-
ick, &c.. for Woodbridge gun-works.

Henry R. Allen, Bridesburgh, receives an order for 4,000 feet lumber
d cord-wood for Woodbridge gun-works.

July, 1874.—Work continues on general fixtures and "hydraulic lift.'

July 8, 1874.—Details confirmed in contract for wire with Trenton
on Company.

Dr. Woodbridge authorized to visit Trenton, New York, and Wash-
gton, about wire.

August, 1874.—Work continues on general fixtures, "hydraulic lift,"
nd wire-splicing machinery.

August 31, 1874.—Trenton Iron Company advise of shipment of one
nnealing of wire, 1,313 pounds.

September, *October*, *November*, *and December*, 1874.—Work continued
n general fixtures, "hydraulic lift," wire-splicing, and reeling-machin-
ry, lathe, &c.

November 25, 1874.—Ordnance Office inquired of as to venting and
fling the 9-inch gun; changes in length and bottom of bore suggested.
o answer on file. The matter is understood to have been referred to
oard on rifling and venting of March 29, 1873.

December 9 *and* 12, 1874.—Explanations of delay in delivery of wire
om Dr. Woodbridge and the Trenton Iron Company.

January, 1875.—Work almost entirely on the cleaning, splicing,
raightening, and reeling of the wire for winding on the 9-inch gun.
r. Woodbridge making frequent trips to Trenton and Washington in
onnection with the annealing and testing of wire.

January 30, 1875.—Trenton Iron Company inquired of as to the amount
f wire on hand and when it can be delivered.

February, 1875.—Preparation of wire for winding continues, the work
onsisting of splicing, cleaning, straightening, and reeling, about 320
ounds of wire being wound on each reel.

February 19, 1875.—Dr. Woodbridge states that he has rejected 10,000
ounds of the steel at Trenton for not coming up to standard required,
nd has verbally agreed with A. C. Lewis, of Brooklyn, N. Y., for steel
ars to that amount to be sent to Trenton Iron Company; incloses
raught of order and specifications.

February 20, 1875.—A. C. Lewis, Brooklyn, written to, inclosing specification as drawn up by Dr. Woodbridge in his letter of 19th.

February 27, 1875.—Dr. Woodbridge submits a proposition (with drawings; see Plate IX) to finish the 9-inch block as a 10-inch gun, with modified exterior, in view of the probable failure of appropriation to cover cost of finishing the 12-inch gun.

Dr. Woodbridge's letter of date on finishing the 9-inch block as a 10-inch gun referred to Ordnance Office, with favorable indorsement.

March, 1875.—Preparation of wire continued. Winding of wire on the gun commenced and continued until the supply of prepared wire was exhausted.

March 12, 1875.—Began winding on the 9-inch gun from 29 reels, and continued without serious interruption till the 20th, exhausting one set of reels of wire—about 9,200 pounds. Twelve layers of wire were wound upon the gun.

March 20, 1875.—Mr. Gill ordered to visit the West Point and South Boston Foundries to learn about rifling and finishing heavy guns.

Having brought the history of the Woodbridge gun up to date, so far as its more salient points are concerned, the following description and drawings are added to render the present and subsequent reports more intelligible.

It is stated in the beginning of this report that the first step in the production of the Woodbridge gun was the winding a large mass of square wire upon a steel tube, which tube subsequently officiated as the lining of the bore of the gun.

This wire (.3″ square) was to be wound 30 strands side by side on the 9-inch gun, and 40 strands on the 12-inch gun, thus securing a considerable obliquity of pitch, which was reversed right and left in alternate layers.

The winding is accomplished while the steel tube is in a lathe, (*a*, Plates I and II,) and necessitates, of course, a traversing wire-carrier, capable of holding 40 reels, each containing a large amount of wire, and the whole endowed with the longitudinal motion required to keep the wires always at the proper angle of pitch. This motion must of course be reversible, and the whole carriage must be capable of oscillating in a horizontal plane through twice the angle of pitch, in order to adjust itself at right angles to the tension of the wires, whether the pitch is right or left.

The gross amount of wire required for building up the 12-inch gun is 100,000 pounds, and it is evident that to contain even a tenth of this full amount on 40 reels the reel-carriage must be an affair of considerable size and weight. It is, in fact, a truck-car, running upon a railway track parallel to the lathe, and separated from it by some 30 feet. (Plates I and II.)

From this reel-carriage the wires converge to a tension winding-rest near the gun, (*c*, Plates I and II,) which controls the tension at which the wires are wound, and traverses in the same manner as the tool of a slide-lathe.

The motions of translation both of the reel-carriage and tension winding-rest may, at the will of the operator, be connected with or independent of the rotary motion of the gun in the lathe—a quick motion being used at the ends in shifting through the arc of twice the pitch-angle to reverse the direction of the coil.

The details of this reversal of spiral are illustrated by Plate VIII.

The winding is continued until the full proposed dimensions of the exterior of the gun have been reached or exceeded.

The gun is then inserted in a jacket of boiler-plate, made in two pieces,

nited by a transverse screw-joint at about the center of length. This ıcket (*e*) and joint (*f*) are partially visible in Plate VI, where *a* repre-ents a portion of the steel core or lining of the bore near the muzzle; , the wire wound thereon; *c*, the end-plate or retaining-flange, screwed n to the muzzle of the tube, to limit the windings at that end; *d*, the xtension-tube, screwed into the muzzle of the tube and passing air-ght through the packing-box (*h*) of the gun case, to allow access to the ıterior of the tube without compromising the air-tight character of the ıcketing for the exterior.

This access is utilized in the earlier stage of the process for ascertain-g the temperature of the mass by the fusion of specimen-bars inserted ı different depths and connected with the indicators, (*l*.) Subsequently is required for the insertion of the air-tubes for cooling the interior of ıe gun.

The packing is effected first by graphite in annular grooves in the ıroat of the gun-case, and further by filling the box (*h*) with iron turn-gs, which will deoxidize any air passing the joint should a reflux ıcur during the heating—a circumstance in itself improbable.

Any inequality of longitudinal expansion between the gun-case and ıe tube of the bore is provided for by the motion of one upon the other, hich this arrangement admits of.

At *g*, Plate VI, is a small trap intended to permit the escape of the r inclosed in the gun-case while preventing reflux by means of melted lver submerging the mouth of the escape-tube.

At *i*, Plate VI, is the trap through which the melted bronze enters e gun-case to fill the interstices of the wire. Before heating it is osed by solid bronze, which, when fused, submerges the mouth of the ap-tube, preventing entrance of air or other material until the supply ' melted bronze from the outside forces an entrance.

At *k*, Plate VI, is a collar upon the extension-tube, bearing against vo iron beams seen in section about it. The office of this arrangement to prevent the floating up of the gun from its less specific gravity hen immersed in melted bronze.

The gun, jacketed in its gun-case, as described, is inserted in the ɜating-case *m*, Plate VI.

This heating-case consists of a large cylinder of boiler-work, in three ıctions, connected by suitable flanges and bolts, as at *n*, Plate VI.

Previous to inserting the gun and gun-case the heating-case has been ıed with fire-clay and ground fire-brick, compacted around a pattern mewhat larger than the gun-case, set eccentrically to the heating-case, order to admit of a flue (*s*, Plate VI) being left in the compacted fill-g on one side of the gun-case cavity.

The whole heating-case is thus comparable to a flask, in which com-ıcted and baked fire-brick dust and clay take the place of molding-ınd, and in which an impression (*r*, Plate VI) has been left of a solid milar to and about an inch larger every way than the gun-case. A rge gate, reaching to the bottom of the gun-case cavity, has also been ft in the clay, which gate first officiates as a flue during the heating ·ocess and afterwards in the normal capacity of a gate for introduc-g the melted bronze at the bottom of the mold.

The internal flange (*p*, Plate VI) serves to support the filling of the ıpe of the flask when it is temporarily removed for the insertion of ıe gun-case in the lower portion.

The weight of the gun and case is sustained by a number of radial ocks of fire-brick, (*u*, Plate VI,) with spaces between them to afford ıady access for the melted metal to the trap *i*.

The upper portion of the heating-case above the line *n n*, Plate VI,

having been removed, the gun in its case is lowered into position on the blocks *u*, and concentric with the mold *r*. The upper half of the heating-case is then lowered into position and secured to the lower half by the flanges and bolts at *n*. Connection is then made between the heating-furnace and the upper portion of the heating-case through the opening *q*, Plate VI, and between the gate *s* and the stack of the heating-furnace by the flange at *t*, Plate VI.

Under the circumstances represented, the flame from the heating-furnace, entering at *q*, will envelop the gun-case, descending along its sides, *r*, and escaping by the gate *s* into the flue *t*, as indicated by the arrows. An arrangement, however, exists by which direct communication between *q* and *t* can be established without the intervention of the channel *r s*.

The current, as indicated by the arrows, is sustained until the melting of the test-rods connected with *l* indicates that the proper temperature has been attained through the whole mass of the gun. The draught is then turned into the stack direct from *q* to *t*, and the melted bronze admitted by the gate *s*, whose functions as a flue have now ceased.

The melted metal rises in the space between the gun-case and the mold, and, entering the gun-case by the trap *i*, fills all the unoccupied space within and without, finally, of course, standing at the same height on both sides and sufficiently above the muzzle *c* to secure a suitable sinking-head pressure.

The flame from the heating-furnace is still allowed to play across the upper portion of the case to prevent that part of the gun from cooling too rapidly, and the air-tube, having been put in operation in the bore of the gun, cools the interior in accordance with the Rodman plan.

When the gun is sufficiently cooled the heating-case is removed in longitudinal halves—being constructed to separate in that way as well as transversely. The fire-clay filling is knocked away and the gun with its case and bronze envelope transferred to a lathe to be finished in the same manner as an ordinary cast gun. It is believed that by coating the gun-case with a vitrifiable compound, the bronze will be prevented from adhering to its exterior, and may be removed in large fragments instead of by the more tedious process of turning down.

The work of reducing in the lathe will remove all traces of the gun case and expose the composite structure of brazed steel wire over the entire surface of the gun.

As the quality of the steel wire is a matter vital to the principle of the Woodbridge gun, great care has been devoted to its preparation, and very stringent conditions have been exacted from its producers, not only in respect to the quality of the steel, but the subsequent drawing and annealing. In point of fact, nearly all the delay in the production of the gun has been attributable to the difficulties encountered in producing wire of the quality required.

The conditions were as follows:

The wire to be drawn square, .3 inches on a side, from steel bars ⅜ inch on a side, and not to break under a torsional strain of 50 pounds, at the end of a lever-arm of one foot in length, applied to one inch of the length of the wire.

Three classes of wire are accepted:

Class 1—In which the fracture (accomplished as above) does not take place until the inch of wire has been twisted seven-tenths of a revolution, (252°.)

Class 2—In which fracture occurs as above when the inch of wire has been twisted from sixty-five hundredths to seven-tenths of a revolution.

Class 3—In which fracture occurs with a twist of from six-tenths to ixty-five hundredths of a revolution.

These conditions are illustrated on Plate VII, from *a* to *e*.

Class 1 is to be used nearest to the bore and the other classes succes-ively added.

In addition to these conditions the wire is required to be annealed vithout trace of oxidation, and to be so handled and packed that it nay reach its destination chemically clean; a set of conditions which ias proved excessively difficult of even partial accomplishment.

The conditions of rolling the ⅝-inch steel bars for drawing into wire iecessarily limit the lengths in which the latter can be produced, about .00 feet being the average. It consequently becomes necessary to have 'acilities for brazing together a number of these lengths to fill the reels of the winding apparatus. Plate VII, *f*, *g*, and *h*, illustrates the method ursued.

The clamp-squares *g* are previously oxidized to facilitate their re-noval after the brazing is accomplished.

A portable brazing-furnace, having flexible connections with gas and last, enables the wires to be brazed *in situ*, between the reel-carriage ind the lathe, when such operation is rendered necessary by the renewal of the reels or the fracture of a joint.

Plate IX illustrates the modified form recommended by Dr. Wood-bridge in case it be decided to finish the 9-inch block as a 10-inch gun, is suggested in his letter of February 27th, 1875.

SUMMARY.

The status of the Woodbridge guns, at the end of the first quarter of 1875, is as follows:

For the 12-*inch gun.*—One steel tube and fittings completed; one ieating-case completed; one gun-case and extension tube completed.

For the 9-*inch block.*—One steel tube and fittings wound with 12 layers of wire, being about 9,200 pounds of the 37,500 pounds which will be 'equired to complete it as a 9-inch block; one heating-case filled with fire-brick clay in proper form for use as described; one gun-case and exten-sion tube completed; 7,200 pounds of bronze cast in ingots, and copper ind tin sufficient to make the additional 15,800 pounds required; 17,000 pounds of wire accepted, but not yet wound.

For the Woodbridge system.—One melting-furnace and connections completed; one heating-furnace and connections completed; one lathe and winding apparatus completed; one reel-carriage and reels with rack and connections completed; one Baxter steam-engine and boiler, pumping-engine, shafting, belting, &c., completed; two blowing-ma-chines, with connections for brazing and for cooling the gun interior, completed; one set of machines for splicing and reeling wire; one hydraulic lift for manipulating the guns and cases; general modifica-tions and fixtures required to fit the rolling-mill for fabrication of the Woodbridge guns completed.

The estimated amounts of bronze (copper 5 parts, tin 1 part) required are:

For the 9-inch block—Gross pounds, 24,000, melted; net pounds, 17,500, poured; in finished gun, 680 pounds.

For the 12-inch gun—Gross pounds, 40,000, melted; net pounds, 36,000, poured; in finished gun, 1,950 pounds.

The loss in combining and casting into ingots of bronze amounts to 8 per cent. in a lot of about 8,000 pounds heretofore cast.

CAPT. WILLIAM PRINCE'S SECOND REPORT, JUNE 30, 1875.

A *résumé* of the history of the Woodbridge system of gun-manufacture was furnished with my report of March 31, complete to that date. At that time the proposed 9-inch gun was represented by its steel tube in the winding lathe, with twelve layers of steel wire, weighing some 9,200 pounds, wound thereon. The first set of reels full of wire had been exhausted in winding this amount. Of the remaining 28,300 pounds of wire, estimated as necessary to complete it as a 9-inch gun, 17,000 pounds were on hand, accepted, and being reeled preparatory to winding. The heating-case, gun-case, and furnaces were ready for use, and the material for the bronze also at hand. The transferring machinery all in working order.

During the earlier part of April the reeling and winding proceeded satisfactorily, notwithstanding some delay occasioned by the fire at the Trenton Iron Works, destroying their wire-drawing machinery.

On the 17th of April 18,200 pounds of wire had been wound and 13,000 pounds more prepared and reeled.

On the 24th 9,000 pounds additional had been wound, bringing the cylinder up to a diameter of 32 inches. By May 1 the winding was substantially completed.

Meanwhile the most important official acts bearing upon the history of the gun had been as follows:

April 27, 1875.—The report of the board on experimental guns, recommending that the proposed 9-inch Woodbridge gun be finished as a 10-inch rifle; approved by the Chief of Ordnance. The gun will hereafter be designated in these reports the 10-inch Woodbridge gun.

May 4, 1875.—The winding of the exterior tie-wire of the gun was completed. The total amount of wire used in the gun was about 34,500 pounds. There was left in store about 2,000 pounds wire.

May 5, 1875.—The gun was removed from the winding-lathe and placed in the lower half of the gun-case.

May 6, 1875.—The jacketing of the gun in its case was completed, and some defects developed in the screw of the hydraulic lift.

May 7, 1875.—The upper section of the heating-case was hoisted off, preparatory to inserting the gun and case. The lathe was dismantled of the winding apparatus, preparatory to its use for turning, boring, and rifling.

May 8 to 10, 1875.—Heating-case and gun-case surfaced and finally prepared for insertion of the latter into the former. Lathe in process of fitting up for turning and boring.

May 11, 1875.—Gun and case successfully inserted into the heating-case.

May 12 to 15, 1875.—Completing connections of furnace and heating-case, putting test melting-rods in position, and preparing for firing up.

May 17, 1875.—Firing-up of heating-furnace begun gradually. Dr. Woodbridge wishing to exclude all possible air from the fuel, the draught-doors under the grate-bars were luted, as well as every other crevice about the furnace, except at the moments of charging fuel and drawing ashes. This absence of natural draught necessitated the use of an accessory fire, higher up in the flue, to draw the products of combustion past the gun.

This heating was kept up with modifications suggested by circumstances for eight days; and, as the operation (an attempt at the protracted heating of a large surface of steel without oxidation) constituted the critical problem in the fabrication of a gun on the Woodbridge system, the process will be best described in detail.

The mechanical arrangements for excluding air from the mass of wound wire by air-tight jacketing of boiler-work has been described in the first quarterly report on the fabrication of this gun.

So long as that jacket, or gun-case as it is called in this report, remained entire and air-tight, the necessary protection was afforded to its contents. Boiler-work, however, when unprotected by water-back, cannot be long subjected to a heat calculated to raise it to the temperature of melted bronze without having its joints demoralized by oxidation, unless special means have been adopted to exclude all deteriorating agencies from the flame by which the heating is effected.

With this view every precaution had been used in the selection of fuel, arrangement of draught, and control over the products of combustion at each moment of the heating.

The fuel intended to be used was a special coke, selected and procured at considerable expense from Pittsburgh on account of its greater freedom from sulphur than that obtainable in the neighborhood. In point of fact, however, charcoal was almost exclusively used in the actual heating.

The arrangements of the furnace-bridge, fuel-chamber, grate-bars, draught-doors, stack, and connections were novel and elaborate. In point of fact, however, none of their contemplated functions were normally utilized. The entire source of natural draught was at first luted up, and an improvised accessory fire in the stack relied upon for drawing the flame from the furnace over the gun-case.

When it became evident, after several days' trial, that sufficient heat could not be produced without air to oxidize the fuel, the other extreme was attempted; the draught-doors thrown open, and an artificial blast driven through the fuel from the blowing-machine, which had been erected to furnish the air required in cooling the gun after casting.

The arrangements for heating coke and stoking from above were largely supplanted in their functions by using the peep-hole at the side for introducing charcoal.

A draught-gauge applied to the furnace between the fuel and the gun-case was supposed to show the strength of the draught by the inward pressure indicated.

In point of fact, however, it simply indicated the tendency to in-draught from the outside atmosphere at the point of its application, or, in other words, the absence of normal draught through the fuel. This was sufficiently shown from the fact that it indicated a maximum at a time when there was practically no draught at all—when every joint and crevice of the furnace had been luted up, and when even the exterior brick-work surface of the furnace had been coated with enamel to shut off the admission of air through the pores of the brick.

When the draught-doors were subsequently opened and a strong natural draught established, the gauge fell; and when an artificial blast was added to the natural draught, it fell still further; and a sufficient addition to the strength of blast would have undoubtedly made it give negative indications.

The contemplated operation of the draught gauge was consequently a simple "confusion of thought," and only failed to be disastrously misleading, from the fact that the entire system it was intended to subserve was abandoned at the very outset, and the gauge had merely to act the part of a vacuum-meter behind the accessory fire, which had been improvised in a joint of stove-pipe fitted into the manhole of the stack above it, a function for which it proved well adapted.

A complicated and delicate apparatus had been erected in proximity

to the heating-furnace for conducting a series of tests on the gases of combustion *pari passu* with their generation. For this purpose the flue connecting the furnace with the heating-case was tapped, and samples of the gas pumped off, as required, through a porcelain tube (to avoid the modifying effect which an iron tube might have exerted upon the hot gases) and a cooler, to a neighboring table. At this table the gas could be tested for free oxygen, for carbonic oxide, and for carbonic dioxide; the first, by admitting a sample of it to a small receiver previously filled with nitric oxide; the second, by the character of the flame in burning; the third, by the amount of calcic carbonate precipitated in a battery of washing-tubes containing a saturated solution of calcic hydrate.

The latter test was intended to be in a degree quantitative. The number of tubes rendered opalescent by the admission of a measured quantity of gas was to be compared with the number so affected by an equal quantity of pure carbonic dioxide. By an oversight in the arrangement, the measuring of the gases in both cases was effected after traversing the tubes, and as no means of estimating the amount abstracted by each had been provided, and the degree of opalescence was a rather vague criterion, the device was abandoned after the first attempt to utilize it.

In point of fact, the only indication finally relied upon was the one universally utilized in furnace operations, viz:

The character of the flame of the burning carbonic oxide, which could have as well been observed by simple ignition of a tap at any desired point in the flue, or at half a dozen points if necessary.

In order to judge approximately of the temperature existing in the heating-case, two rods, one of bronze, the other of copper, were inserted in the side of the case in such position that their inner ends were visible through a peep-hole at the top. Both were capable of replacement, and the temperature was endeavored to be kept as nearly as possible between the melting-points of these two metals, as indicated by the fusion of one or both. The method of determining the proper temperature of the interior of the gun by the successive fusion of specimen bars at different heights has been already described in the first quarterly report on the gun.

Having enumerated the fittings and accessories of the heating apparatus, with their contemplated functions, it remains to describe the actual steps in the heating process.

On the first day (May 17) the furnace was started with charcoal, and, all access of air through the grate-bars being cut off by the closing of the draught-doors, it was found necessary to produce an artificial draught by connecting an accessory fire with the stack, thus drawing through the heating-case the products of such combustion as was possible in the furnace under the circumstances.

The heating of the gun proceeded, of course, very slowly, forty-eight hours having expired before the melting of the highest specimen rod announced that the heating had penetrated three feet from the top of the gun-case.

During this time the furnace was operated as if the fuel, like gunpowder, contained within itself the oxygen necessary for its own combustion. Every usual means of access of air was cut off. The draught-doors under the grate-bars were closed and luted, and the cover of the stoking-hole above similarly luted except at the moments of feeding the charcoal and coke. Under these circumstances it was really an apparent anomaly that combustion occurred at all, and its being sustained is

only explicable by the fact that the fire higher up in the stack produced such a vacuum by its draught that air filtered in through the walls of the furnace on all sides, through pores and imperfect joints.

The fuel was almost exclusively charcoal, though coke had been originally contemplated, as stated, and to avoid the access of air afforded by the momentary opening of the stoking-hole, the fuel was largely introduced at a small aperture in the side of the furnace originally intended as a peep-hole.

The character of the gases passing into the heating-case was continually checked by observing the appearance of its flame as burned at the end of the tap-pipe described. All other observations and tests of the gases were relinquished after the first attempt.

The immediate effect of denying to the fire a supply of air in a natural direction from the bottom, through the whole mass of fuel, which would have effectually consumed its oxygen before entering the heating-case, was to stimulate the entrance of air at other points, many of them *above* the surface of the fuel, and thus to allow free oxygen to be mixed with the gases entering the heating-case.

To remedy this observed defect, Dr. Woodbridge, on the third day, had the entire exterior of the furnace served with two coats of a composition of red lead and rosin, to close the pores of the brick-work.

The upper stoking-hole was kept luted, and the fuel—now almost exclusively charcoal—was administered in lumps through the peep-hole, as previously mentioned. The draught-doors under the grate-bars were also, of course, perfectly luted, and every precaution seemed to have been taken to render combustion difficult and the further heating of the gun impossible.

During all this time, it should be observed, the fire in the stack was kept actively burning, and, notwithstanding the practical absence of all draught through the furnace, the so-called draught-gauge was indicating the strongest draught at any time shown—in reality indicating the vacuum created by the draught of the fire in the stack.

This state of things continued until the night of the 20th–21st of May, when it became evident to Dr. Woodbridge, as to every one else present, that if the gun was ever to be heated throughout to the temperature of melted bronze, more fuel must be consumed and a supply of oxygen for the burning of that fuel must be furnished.

The closed condition of the furnace was also developing complications in the accumulations of slag and ash.

A complete change of tactics was entered upon. The draught-doors under the grate were thrown wide open, a full natural draught supplied, the accessory fire in the stack withdrawn, the grate cleared, and a supply of fuel consumed commensurate with the increased oxidizing facilities.

The effect was what might have been anticipated. A free supply of air being afforded through the proper channel, all surreptitious entry by leakages at improper points at once ceased.

The gases entering the heating-case were all obliged to traverse the thick mass of burning fuel before reaching that point, and were not only thoroughly stripped of free oxygen, but remained powerfully deoxidizing from the unsatisfied affinities of the carbonic oxide.

The draught-gauge, now that a strong natural draught had been established, fell to a quarter of its previous registrations. The outside air was no longer pressing at its valve for entrance to an asphyxiated furnace.

The heating of the gun-case progressed so favorably that, on the after-

noon of May 21, Dr. Woodbridge concluded to supplement the natural draught by a blast introduced under the grate-bars. The result was entirely successful. The gun heated more in ten hours than in the previous twenty-four.

At 7 p. m. of May 21 the second specimen bar was fused, showing that the melting-heat had extended from the muzzle to near the trunnions of the gun.

On the 22d of May the last trace of the late process was abandoned, in the entire exclusion of coke from the firing and the abolition of stoking through the peep-hole. The flame of the gas passing from the furnace was the only test used in managing the fires. About three barrels of charcoal were consumed per hour.

On the 23d of May the third specimen bar, placed within two inches of the bottom of the bore, began melting at 9 p. m. and fell at 10.45 p. m.

On the 24th of May, at 3 a. m., the gun was so nearly heated throughout that fires were started in the melting-furnace preparatory to running in the bronze. The charge consisted of the following:

	Pounds.
Bronze, ($\frac{1}{6}$ tin,) in pigs	7,100
Copper, in pigs	14,000
Tin, in pigs	2,800
Total	23,900

The estimated weight of bronze required to fill in and around the gun, case, flues, &c., was 17,000 pounds, so that a surplus of over three tons of metal was melted.

The melting of this metal was a mere commonplace incident in the fabrication of the gun, involving no peculiar conditions, and, as part of a work where so much was unavoidably tentative, might well have been left to be accomplished in the ordinary way.

A furnace perfectly suited for the purpose might have been erected after the model of those of any of our successful bronze-founders.

The occasion was, however, deemed opportune by the inventor for testing certain views with reference to the application of hot draught to reverberatory furnaces.

A complicated and costly furnace was accordingly erected, in which the flame, after sweeping over the hearth, rose and impinged upon a series of cast-iron tubes, enveloping them in its approach to the stack of the furnace.

The fire-place of the furnace had the usual arrangements of draught-doors for controlling the natural draught through the grate-bars, but was so arranged that this draught could be substituted for by hot air drawn through the cast-iron tubes on which the flames of the furnace impinged.

An experimental firing of this furnace had demonstrated as the first fact developed, that the hot-air tubes having been introduced must be used to save them from melting, thus rendering entirely nugatory all the arrangements for ordinary draught with the time and money expended on their construction.

The subsequent use of the furnace showed that the hot-air tubes could not be saved from melting in any event. They barely survived the earlier stages of firing the furnace, and fell in a fused mass on the hearth just after the bronze had been withdrawn. A few moments sooner and they would have vitiated the entire operation of casting the gun.

Thus was an unnecessary element of uncertainty introduced into a trial already burdened with uncertain elements inseparable from the system, and the success of the whole enterprise imperiled to test a question entirely outside of the scope of the investigation.

The melting-furnace, like the heating-furnace, was a success only in so far as its construction and operation were normal and usual, and failed in every feature where they were novel or fanciful. Whatever success they achieved was in spite of rather than on account of their original feature.

These plain statements of facts, observed by the officer charged with the duty of observing them, are submitted as conformable with the spirit of the last clause of the order under which this report is made.

The bronze having been brought to the proper condition for pouring, was admitted to the heating-case (now become a flask) after suitable preparations, and the pouring proceeded in the most satisfactory manner until just before reaching the top of the gun-case the supply of metal from the furnace gave out.

Dr. Woodbridge, who was personally superintending the pouring, immediately directed that tin be prepared, by melting it in a pot over a portable furnace. Colonel Treadwell suggested using the still heated melting-furnace for the purpose, which was immediately done, and about 7,500 pounds of tin was melted and poured from ladles into the top of the heating-case, and partially also into the inner gun-case, which was now open at one portion of its upper surface.

The bronze sank rapidly, and the tin was continuously added during the day and night of May 24–25, keeping the sinker nearly full all the time.

At 2 a. m. of the 25th the cooling blast of air was turned into the bore of the gun, and at 2 p. m. this was supplemented by a jet of water spray, which was used at intervals until 5 p. m. of the 27th, when water was run through the bore until cold.

The tin, remaining fluid, of course, long after the bronze had solidified, sank into every crevice and fissure that was opened by shrinkage, and spurted from every joint in the heating-flask during the whole of the 25th and 26th. This percolation of the still fluid tin not only absorbed all sinking head, but left the upper part of the gun far above the surface of the metal, though it was hoped that the soldering of the mass had been effected at the time when the metal stood at its full height.

Of course the failure of the metal to fill the mold, when so large a margin (6,900 pounds) had been allowed, was a source of surprise to all concerned, and the subsequent engulfing of 7,500 pounds of tin but added to the mystery.

On removing the shell of the heating-flask, however, the cause was evident. The filling of the flask, consisting of compacted fire-clay and ground fire-brick, as already described, was infiltrated with tin and bronze for from 4 to 8 inches from the surface of the casting on all sides, forming a tenacious conglomerate, adhering to the gun, and resisting all attempts to spall it off beyond certain limits. The simple fact appeared to be that the matrix, being as hot as the melted metal it contained, induced no chill or viscosity in the metal, which consequently traversed the pores of the mold without hinderance, completely saturating the walls of its prison to a limit determined by their temperature and the pressure of the superincumbent fluid column.

In a sample of the conglomerate, regarded as a fair average specimen, one-fourth of the entire volume was found to be bronze. In a specimen from the base of the casting one-third of the volume was bronze.

This is certainly a remarkable fact, even regarded in no higher light

than as exhibiting the porosity of compacted masses which are sensibly solid. That a concrete formed of finely-ground fire-brick and fire-clay, thoroughly compacted by the most persistent ramming, should still possess vacuities amounting in volume to one-third of its entire bulk, is a state of things which would hardly have been anticipated. Not only the fire-clay but entire fire-bricks, wherever they had been used near the casting, were infiltrated at the rate of about 2½ pounds of bronze to a brick.

It was estimated that the conglomerate mass clinging to the casting contained on an average 140 pounds of bronze to the cubic foot, or a total of 11,000 pounds.

The vertical gate which stood beside and led to the bottom of the gun was enveloped in the agglutinated mass.

It is difficult to conceive of a substance more refractory than the bronze conglomerate. With the hardness and grittiness of stone it possessed the toughness of bronze. To chip it with chisels and sledges was as tedious as working on cast iron, and vastly more wearing on the tools. There was nothing for it but to put the whole mass bodily into the lathe and endeavor to remove the entire coating by cutting it up into rings which might be broken away.

In front of the trunnions, however, a considerable portion of the incrustation was removed in fragments by driving wedges between the bronze and the gun-case where there was to some extent a solution of continuity.

After all that could be conveniently disposed of in this manner had been removed, the extension-tube was cut off at the muzzle, a center inserted and another center hole bored in the base, an inch and a quarter eccentric to the gun on the side of the still-attached gate, to assist in counterpoising the weight of the latter. The gun was then placed in the lathe and further counterpoised by weighting the face-plate. The upper exposed portion of the gate was removed, and the base of the gate cut through to detach it from its horizontal branch. The front of the gun was stripped of the partially-burned gun-case, and a portion, between 3 feet and 5 feet, in front of the trunnions turned down some 3 inches to determine the height to which the bronze had consolidated the gun. The bronze soldering was found to be complete and sound to a distance of 4 feet in front of the trunnions, from which point to the muzzle the wire of the gun was soldered more or less completely by tin.

The attempts at turning off the incrusting material had indicated that its removal in that way would involve an immense amount of time and labor, a very light feed being possible, and tools constantly being disabled.

After an unsuccessful essay at sawing the conglomerate with a circular set of cutters, it was resolved to attempt again the separation of fragments from the mass by the use of wedges driven between the bronze and gun-case or between the concrete and bronze wherever the least appearance of joint gave hope of effecting rupture.

By the judicious and persistent use of fine steel wedges, kept constantly dressed, and by relays of men with heavy sledge-hammers, a longitudinal tract was laid bare down to the bronze, for the whole length of the incrustation, on the side of the gun opposite the gate.

Lines of wedges, approximately corresponding to longitudinal elements of the gun, were then inserted and driven, as nearly simultaneously as might be, between the crust and the bronze. By this means some large fragments were detached on both sides of the tract already uncovered, until finally only the great longitudinal excrescence

containing the gate remained to be detached. This was finally effected by lines of wedges and long-continued hammering, and on the 26th of June—four weeks from the opening of the flask—the gun was finally emancipated from its entangling alliances.

As soon as the whole base of the gun was uncovered, a cut was commenced behind the position of the cascable ring, and at the time of making this report the cut has been carried in some 6 inches, exposing a section of 18 layers of steel and bronze. The brazing is, to all appearance, complete and perfect at this portion of the casting. The condition of the gun may therefore be stated as follows:

From the cascable to a point 4 feet in front of the trunnions the wire is, to all appearance, solidly brazed with bronze; and the mass within those limits probably constitutes a sound, fair, practical illustration of the Woodbridge system of gun-construction, as contemplated by the inventor.

From the point indicated to the muzzle the wire is soldered more or less perfectly with tin.

It is the opinion of Mr. Gill, the foreman in charge of the work, that the gun can be best and most neatly finished for proof by turning down the tin-soldered portion to a diameter less, by the thickness of one layer of wire, than that of the contemplated profile, and then bringing up the dimensions by winding a single tie-wire upon that portion, finishing by turning off a surface-shaving from the whole. The extreme muzzle to be finished with a thimble fitted on the steellining tube, and lapping a rebate turned in the wire-mass.

CAPT. WILLIAM PRINCE'S THIRD REPORT, SEPTEMBER 30, 1875.

On the 14th of August, 1875, work on the Woodbridge gun was resumed. The first week was consumed in repairing the lathe and recentering the gun—the first centering having been intentionally eccentric, to balance the large adhering mass of metal and concrete on the gate side of the gun.

The gun, on its new centers, was turned at the larger end to fit a large chuck on the face-plate. Two deep cuts were then turned, one on each side of the trunnions, to free the adhering mass which encumbered them, which was successfully removed. From this point the turning has regularly progressed at various points on the gun; the partially-soldered portion near the muzzle being reduced by driving off annular shells, or short tubes of wire, after loosening by grooves turned through the layers at short intervals.

A deep cut, down to the steel core, was begun behind the breech, being the only point where an extended transverse section could be exposed. This cut will also demonstrate the concentricity of the rear of the tube with the present centering.

The shell, or "gun-case," has been nearly all turned off, and the forward portion of the gun reduced to nearly its ultimate dimensions, as proposed.

Boring was begun on the 16th instant and has been carried on simultaneously with the turning. The first cut (completed on the 28th instant) increased the diameter from $7\frac{3}{8}$ inches to $8\frac{1}{2}$ inches. The next cut will increase it to $9\frac{5}{8}$ inches, after which two cuts, of $\frac{5}{32}$ and $\frac{1}{32}$ radial increase, respectively, will finish the cylindrical portion of the bore. These cuts will require about 10 days each for the second and third, and about one week for the finishing cut, which latter will be run day and night.

In the course of the turning and boring the following developments have been noted:

I. The steel core has not bent or sprung in heating or casting. This was demonstrated by inserting a straight-edge, $7\frac{5}{16}$ inches wide, which was entered for its full length, without resistance, and rotated.

II. The bronze, which was stated in last quarterly report to extend to four feet in front of the trunnions, is found, on removing the outer layers, to have risen (perhaps by capillarity) some ten inches higher than indicated on the exterior, the gun being fairly brazed to a point of its length nearly five feet in front of the center of the trunnions.

III. Certain marked changes have taken place in the nature of the iron in the jacket, and the steel of the gun. These changes may be more or less attributable to any or all of the unusual conditions to which the material has been subjected. Their explanation is not attempted; in fact, with our present knowledge, they are not reconcilable among themselves; but the facts are recorded as a contribution to the very limited literature of protracted annealing of iron and steel in presence of excess of carbon, and of the influence of tin, and alloys of tin, upon iron and steel at high temperatures.

To begin, then: The jacketed gun, when ready for the furnace, is a mixed structure of iron and steel, the tube and wound mass representing the steel, while iron constitutes the jacket, end-flanges, and filling-plates. The latter are used to replace the wire in the spaces left vacant at the end of each layer by reversing the pitch in winding, and are thus particularly mentioned, because from their position—representing, as they do, so much absent steel wire—they were subjected to *precisely* the same influences as the wire they partially replaced.

In order that the bronze might exercise its full soldering power upon the steel elements of the structure, precautions, almost finical, were adopted to preserve their surfaces bright and chemically clean. They were literally handled with gloves in building up the gun.

The treatment of the iron jacket, or "gun-case," was in marked contrast with that of the steel parts. Here amalgamation with the bronze was rather to be discouraged. The case was made of ordinary boiler-plate, roughly scoured on the inside, and painted on the outside with a siliceous coating, which was intended to vitrify and enamel its surface when heated.

It was hoped by this means that the bronze on the outside might be removed in large fragments, instead of by the tedious operation of turning down.

The compound mass of steel and iron thus described was subjected, for one week, to a heat ranging up to that of melted bronze, in a closed chamber, immersed in gases of a "reducing" or carbonizing tendency. At the end of this period it was suddenly immersed in a bath of melted bronze, under great pressure—melted tin being substituted for bronze in the upper, and least pressed, portion of the column.

In this bath it was allowed to cool gradually from the center until the mass became solidified—an operation requiring between four and five days.

The condition of things which would be naturally anticipated under these circumstances might be thus stated:

The iron and steel should have been rendered extremely soft.

The tension of the wound wire should have been somewhat relaxed.

The adherence of the bronze to the clean steel surface should have been very perfect.

The adherence to the interior of the iron "gun-case" should have

been less perfect, and, on the exterior or enameled surface of the "gun-case," there should have been scarcely any adherence.

The real facts are as follows:

The steel wire is everywhere much harder than when wound upon the gun. This is amply shown by its action upon the tools in turning, and by its flying off, with almost glassy fracture, under the chisel.

This increased hardness is, however, unaccompanied by the increased fineness of structure which ordinary hardening induces. The fracture is, for steel, very coarsely crystalline; much more so than when originally wound.

The iron is everywhere quite soft, and apparently very little changed either in appearance or qualities.

The consolidation of the steel wire by the bronze seems to be very thorough. It is not, however, so perfect but that wires are occasionally "ripped up" in turning by a dull tool or an over heavy feed.

The union of the bronze with the iron, however, is practically perfect. In no instance has it been possible to open a joint between these two materials when in contact; and that contact exists over the entire surface of the iron; for, not only was all oxide-scale removed from the inside by the carbonizing influences present, but on the outside the bronze burrowed between the iron and the enamel, lifting the latter off from the former and attaching itself firmly to the clean surface of iron thus exposed. So that we find the following succession from the outside inward, viz:

Conglomerate, (fire-clay and bronze.)
Bronze.
Scale, (enamel and oxide.)
Bronze.
Iron, (gun-case.)
Bronze.
Steel, (gun proper.)

The imperfect union between the bronze and the layer of scale formed by the separated enamel was, in point of fact, the joint that was availed of in removing the masses of conglomerate that enveloped the gun at its first emergence from its flask.

The alteration of the steel wire should have been stated to have been much greater near the muzzle of the gun—not only from the much longer time during which it was heated, but owing probably to a partial alloy being formed between it and the tin. The iron at this point is largely altered or consumed.

It is well known that iron, even at moderate temperature, forms an alloy with tin; the fabrication of tin plates being in fact alone rendered possible by this property.

The tension of the wire is greater in the finished gun than when originally wound. This is shown by the retraction of the ends when a strand, detached from its neighbors, has been cut across.

All these circumstances seem to point to the futility of insisting upon finely-drawn conditions of original tempering, cleanliness of surface, and tension in winding of the wire used in guns of this system.

The fact being that the subsequent processes to which the wire is subjected utterly overwhelm and mask its original features and condition.

It may even be doubted if good iron wire, in its usual condition, would not, if substituted for the steel, produce a mass whose properties could more confidently be inferred from the materials employed than can those of the present structure.

At noon to-day, and subsequent to the writing of the earlier portion

of this report, the cut behind the cascable of the gun has reached the surface of the tube, which proves to be less than $\frac{1}{32}$ of an inch eccentric with the present centering.

The most important point developed by this cut, however, is that the heating just fell short of being thorough at this the center of the largest mass and last heated portion of the gun. The two layers of wire nearest the core are at this point imperfectly brazed, though the infiltration of the bronze is complete. This indicates a very close approximation to the right moment having been seized for pouring the bronze, but suggests a slightly-increased continuance of heating in any future operations. As this imperfect union can extend but a very short distance, and does not alter the appearance of the surface, its presence at this point is not deemed prejudicial.

FOURTH REPORT, MADE BY MAJOR T. J. TREADWELL, DECEMBER 31, 1875.

Since October 1, 1875, a cut was made down to the interior tube of the gun to ascertain the concentricity of the tube; the centering of the gun in the lathe was found to be not more than $\frac{1}{32}$ of an inch out of true, and the gun was recentered.

The trunnions were turned down to the full size the casting would bear, viz, 11″.75 diameter, and their faces turned off and finished. The finishing of the turning of the body of the gun was completed, as far as practicable, before shrinking on the muzzle-rings. A second cut was made in the bore of the gun, increasing the diameter from 8″.625 to 9″.625, and a third cut, increasing the diameter from 9″.625 to 9″.94; the latter boring was found to be smooth, and on star-gauging did not vary even 0″.0025 in diameter. The cutting-tool was constantly lubricated with oil by means of a pipe which supplied the tool with the lubricant during the whole boring, showing that with this precaution a smooth bore is obtainable; the same means will be used in rifling the gun to insure smoothness of grooves.

The alignment of the trunnions was verified.

The wrought-iron muzzle-rings, which are being made at Washington navy-yard, under the direction of Dr. Woodbridge, were not received at this time, so the work was continued on the gun of planing between the trunnions, which was completed, and the chipping of the irregular parts around the trunnions to form the rimbases partly done. Six of the wrought-iron muzzle-rings and the steel muzzle-collar were received; the six rings were shrunk on the gun with a tension of about 0″.01.

The last boring, to full size, having to be run night and day until complete, it was deemed best not to make the finishing-cut of the bore until all the muzzle rings were shrunk on and the muzzle-collar secured to its place. The six muzzle-rings were partially turned down.

The work is necessarily slow, as one man can only work at the lathe at a time. About 2,570 hours have been consumed during the quarter, the work having been pushed without regard to day's-work of 8 hours.

It has been found that the steel wire toward the interior is much softer than that on the exterior of the mass, and more of the nature of well annealed steel; especially is this so in those parts of the gun where the brazing is perfect. The unbrazed portion of the gun extends 61″ from the face of the muzzle.

The groove in the rifling bar has been finished and the necessary tools for boring and turning made and kept in order, as well as the arrangement and tools for planing the metal between the trunnions.

The work remaining to complete the gun is: shrinking on the three additional muzzle-bands, (these have not yet been received,) screwing on the muzzle-collar, finishing the turning of all the bands and collar to true size, making the last cut in the bore of the gun, rifling and venting and cutting off the gun at the breech, and finishing this part.

A ring was cut from the body of the gun where the brazing was perfect—at a point about three feet in front of the trunnions; the gun at this point was 38″ in diameter; .9″ was turned off, and a 1″.5 × 1″.5 ring 29″ diameter cut from this point. This ring, on being cut, opened but 0″.02, showing almost no initial strain at this part of the gun. Portions of this ring will be prepared for Colonel Crispin for test of its tensile strength. A portion will be sent to Lieutenant Metcalfe for exhibition with the Woodbridge gun-plant at the Centennial Exhibition, and specimens sent to the Ordnance Office, to Dr. Woodbridge, and retained at this arsenal.

It is estimated by Mr. Gill, foreman in charge of the work, under the direction of Dr. Woodbridge, that the gun will not be finished prior to March 1, 1876.

FINAL REPORT ON THE FABRICATION OF THE 10-INCH WOODBRIDGE GUN, MADE BY MAJ. T. J. TREADWELL AT FRANKFORD ARSENAL, 1876.

FRANKFORD ARSENAL, *April* 19, 1876.

SIR: I have the honor to submit the following report of the completion of the work on the 10-inch Woodbridge gun since December 31, 1875:

The three additional muzzle-rings were shrunk and the muzzle-collar screwed on, and the turning to finished diameters of the muzzle-rings and collar completed. The last cut of the bore made to full size, increasing the diameter from 9″.94 to 10″.003. The work on this cut was continuous, oil being very freely used at the cutter, and the result was a very smoothly and accurately finished bore; this cut was made in seventy-six hours. Star-gauging the bore showed a variation of only 0″.001.

Rifling was commenced January 18 and finished on the 27th, an arrangement being made for securing a constant supply of oil to the rifling-tool as well as for collecting and removing the chips, thus insuring very remarkable smoothness of grooves.

The hole for the vent-piece was bored and tapped at a distance of 2″.5 to the left of the axis and 3″.5 from the bottom of the bore, and the vent-piece finished and screwed in.

The portions of the exterior of the gun requiring hand-filing were attended to and the breech end cut off and finished, the line of metal and position of front sight marked and sight made. The gun was balanced on its trunnions on iron rails, 50 pounds at the muzzle holding it in equilibrium, being equivalent to 100 pounds breech preponderance.

Attached are copies of reports of Lieutenant-Colonel Crispin of tests of specimens taken from the muzzle end of the tube and from the ring cut in front of the trunnions, referred to in my report of December 31, 1875, also specimens of the same ring finished to test the brazing of the wires.

A ring cut from the muzzle end of the tube was tested here by being bored slightly tapering and by forcing a tapered mandril into it. It extended 0″.085 without rupture, leaving a permanent set at 0″.075.

The principal dimensions of the finished gun are as follows: Whole length, 174 inches; whole length of bore, 155 inches; greatest diameter, 36 inches; diameter of trunnions, 11.75 inches; weight of gun, 30,300 pounds; preponderance at breech or seat of elevating arc, 100 pounds. Drawings of the finished gun, showing construction, muzzle and collar-rings, &c., of the ring and specimens tested, and ring from muzzle end of tube, accompany this report. (Plates X and XI.)

As you are aware, there were many difficult problems presented consequent upon this entirely novel gun-construction, and, briefly, all the steps of manufacture of the gun and its peculiar plant were experimental. The measure of success attained, although not altogether complete, may nevertheless be referred to with satisfaction, and I desire to put on the record that this is due in a very great degree to the practical mechanical skill and ingenuity, untiring care and energy, brought to bear upon the subject by Mr. Jabez H. Gill, who has had constant superintendence of the work from its inception.

Very respectfully, your obedient servant,

T. J. TREADWELL,
Major of Ordnance, Commanding.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

TESTS OF SPECIMENS OF WOODBRIDGE GUN.

UNITED STATES ORDNANCE AGENCY,
New York, March 29, 1876.

SIR: I have the honor to present below the results of tests made at this agency of specimens from the steel tube and wrapped body of the Woodbridge 10-inch rifle:

Specimens and marks.	Specific gravity.	Tensile strength per square inch.
STEEL TUBE.		
		Pounds.
C, tangential ..... T. S...	7.8532	88,375
D, tangential ..... T. S...	7.8656	89,316
E, longitudinal ..... L. S...	7.8582	85,385
F, longitudinal ..... L. S...	7.8730	85,576
BODY OF GUN.		
A, tangential ..... T. S...	7.9131 }	Broke at shoulder—too sharp.
B, tangential ..... T. S...	7.8945 }	
G, tangential ..... T. S...	Not taken.	92,500
H, tangential ..... T. S...	7.8820	91,514
I, tangential ..... T. S...	7.9081	88,978
J, tangential ..... T. S...	7.8925	92,160

The fractures of the specimens were uniform in granulations, those of the wire the finer.

JOHN G. BUTLER,
Captain of Ordnance, U. S. A.

MARCH 30, 1876.

Respectfully forwarded to the commanding officer of Frankford Arsenal.

S. CRISPIN,
Lieutenant-Colonel of Ordnance, Commanding.

UNITED STATES ORDNANCE AGENCY,
New York, March 31, 1876.

SIR: I have tested the two longitudinal specimens (wire cemented) from the Woodbridge gun, with the following results:

Referring to accompanying sketches, (Plate XI.) Fig. I represents the specimens. Upon applying a weight of 33,700 pounds the specimen broke through the lines A B. Not knowing that the shoulders S were inserted so deeply, I reduced the diameter of the next specimen, as shown in dotted line, and the fracture of course occurred at G and D. The area of the broken section A B was 1.6264, (the fracture occurred *through* the brazing, and consequently the strain applied was 21,930 pounds per square inch. If a couple more specimens can be prepared according to Fig. II, I have no doubt more satisfactory tests can be made.

JOHN G. BUTLER,
Captain of Ordnance, U. S. A.

[Indorsement.]

Respectfully referred to the commanding officer of Frankford Arsenal with the request that the specimens indicated on the inclosed sketch, Fig. II, be furnished this office.

Please return this paper.

S. CRISPIN,
Lieutenant-Colonel of Ordnance, Commanding.

UNITED STATES ORDNANCE AGENCY,
New York, April 10, 1876.

SIR: I have the honor to report that I have tested the longitudinal specimens from the Woodbridge gun last sent from Frankford Arsenal, with the following results:

Specimens longitudinal pulled perpendicular to surface of brazing. (Plate XI.)

Specimen.	Diameter.	Area.	Tensile strength per square inch.	Fracture.
	Inches.		*Pounds.*	
M	0.650	0.3320	6,325	Through brasing surface.
N	0.650	0.3320	24,400	

Very respectfully, your obedient servant,

JOHN G. BUTLER,
Captain of Ordnance.

Respectfully referred to the commanding officer of Frankford Arsenal for his information.

S. CRISPIN,
Lieutenant-Colonel of Ordnance, Commanding.

WINDING MACHINERY OF WOODBRIDGE GUN.

SECTION ON A. B. OF PLATE I. [SUBSTANTIALLY.]

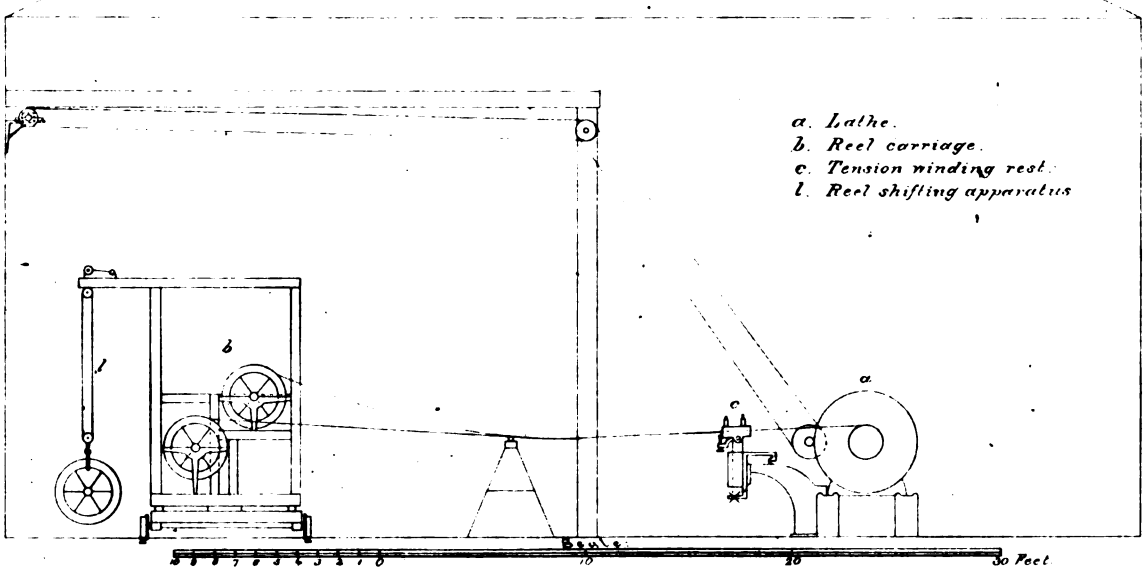


Plate II.

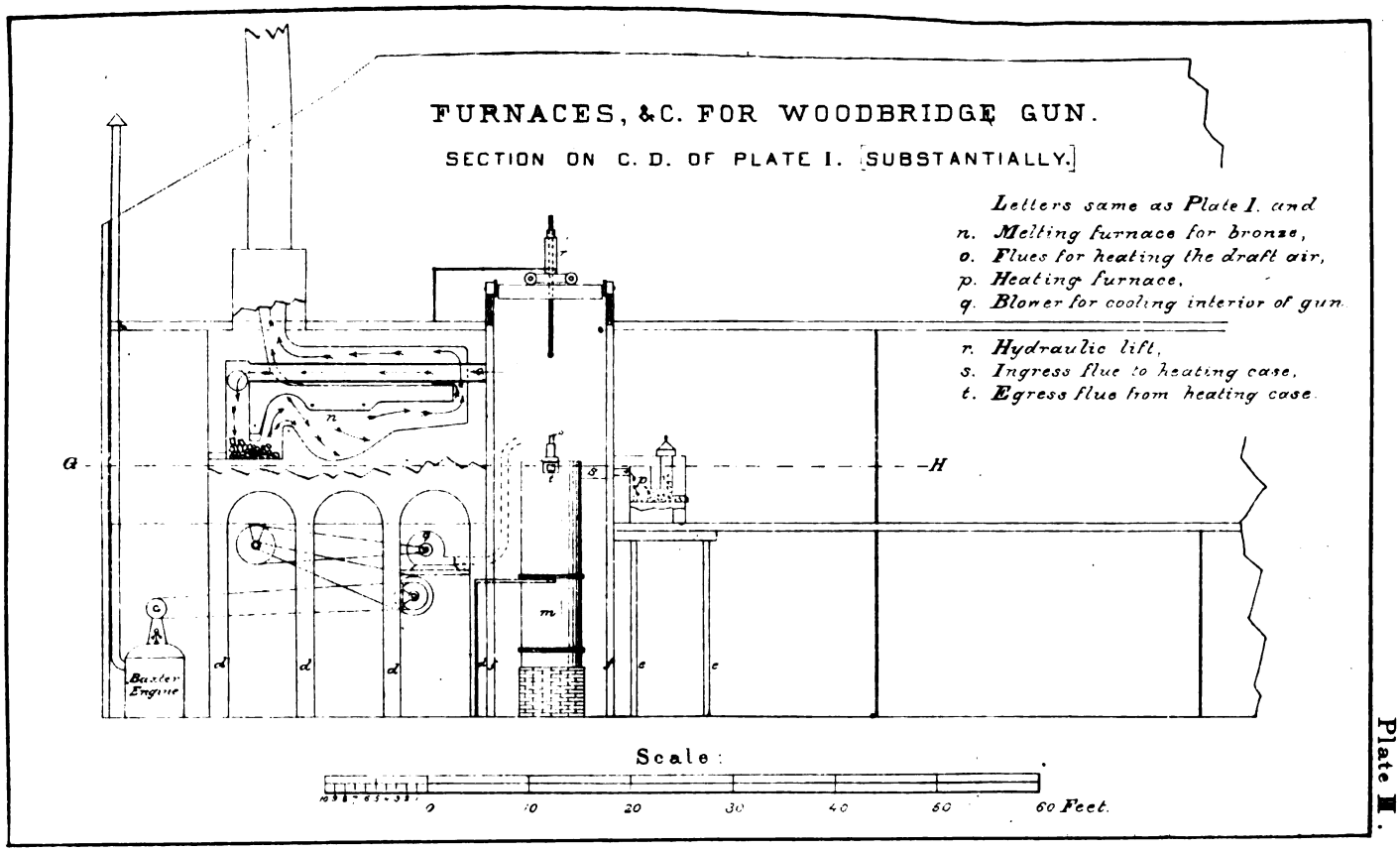
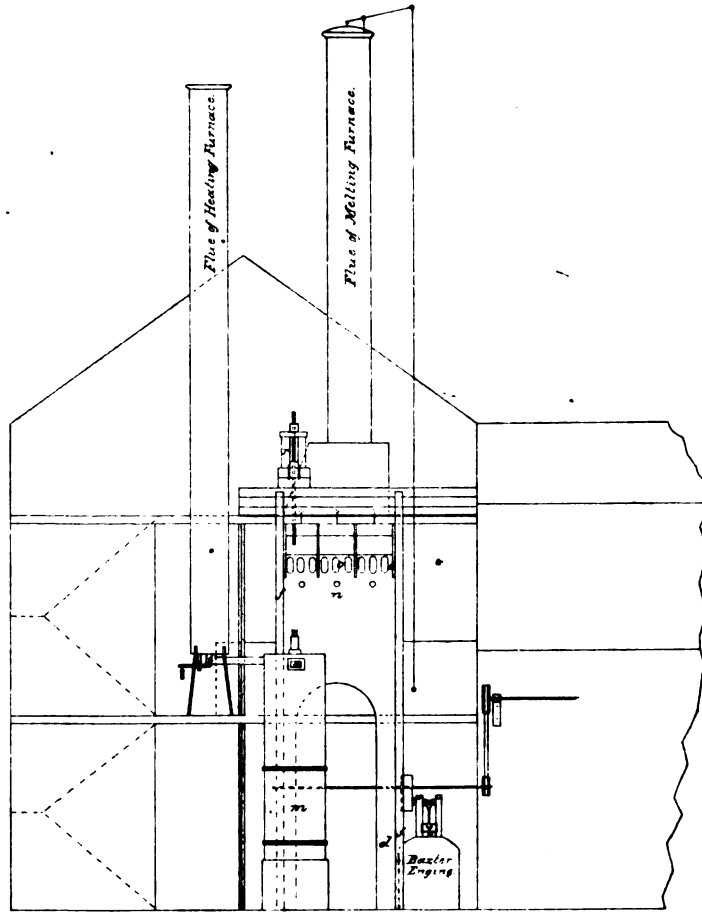

FURNACES, &C. FOR WOODBRIDGE GUN.
SECTION ON C. D. OF PLATE I. [SUBSTANTIALLY.]
Letters same as Plate I. and
n. Melting furnace for bronze,
o. Flues for heating the draft air,
p. Heating furnace,
q. Bloner for cooling interior of gun.
r. Hydraulic lift,
s. Ingress flue to heating case,
t. Egress flue from heating case.
G
H
Baxter Engine
Scale:
0
10
20
30
40
50
60 Feet.

Plate II.

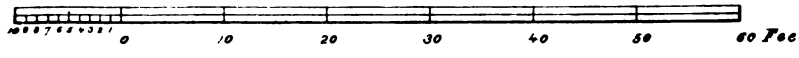
HEATING APPARATUS, &c. FOR WOODBRIDGE GUN.

SECTION ON E. F. OF PLATE I. [SUBSTANTIALLY.]



Letters same as Plate I. and III.

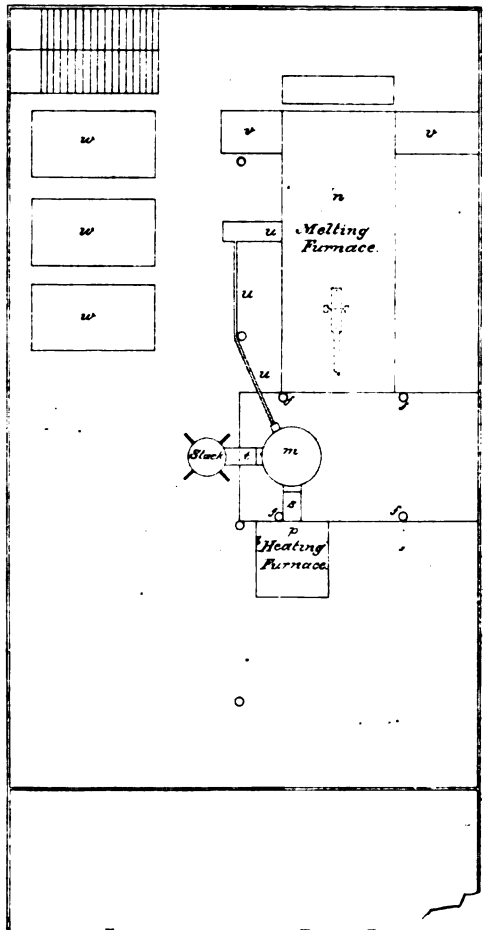
Scale:



SECOND STORY OF ROLLING MILL.

FURNACES, &C. FOR WOODBRIDGE GUN.

SECTION ON G. H. OF PLATE III. [SUBSTANTIALLY.]



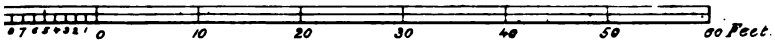
Letters same as Plates I. and III. and

u. Tap-hole and conduit for melted bronze,

v. Platforms for stoking,

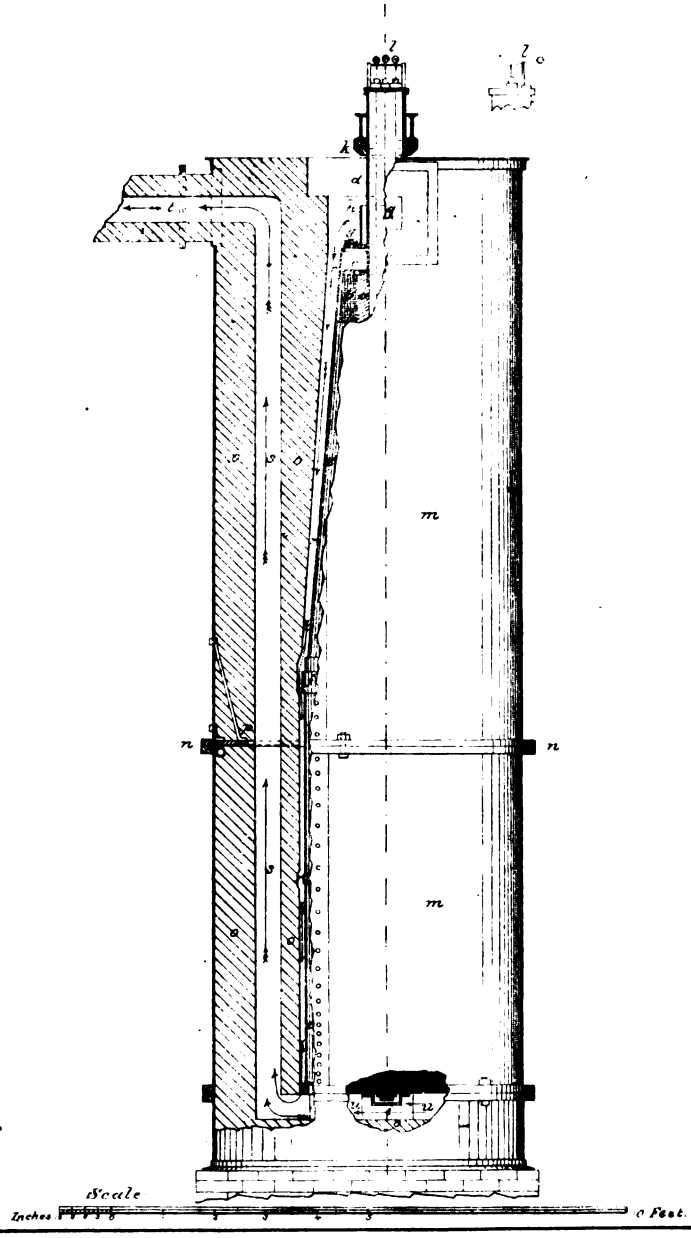
w. Flasks for draining off unused metal.

Scale:



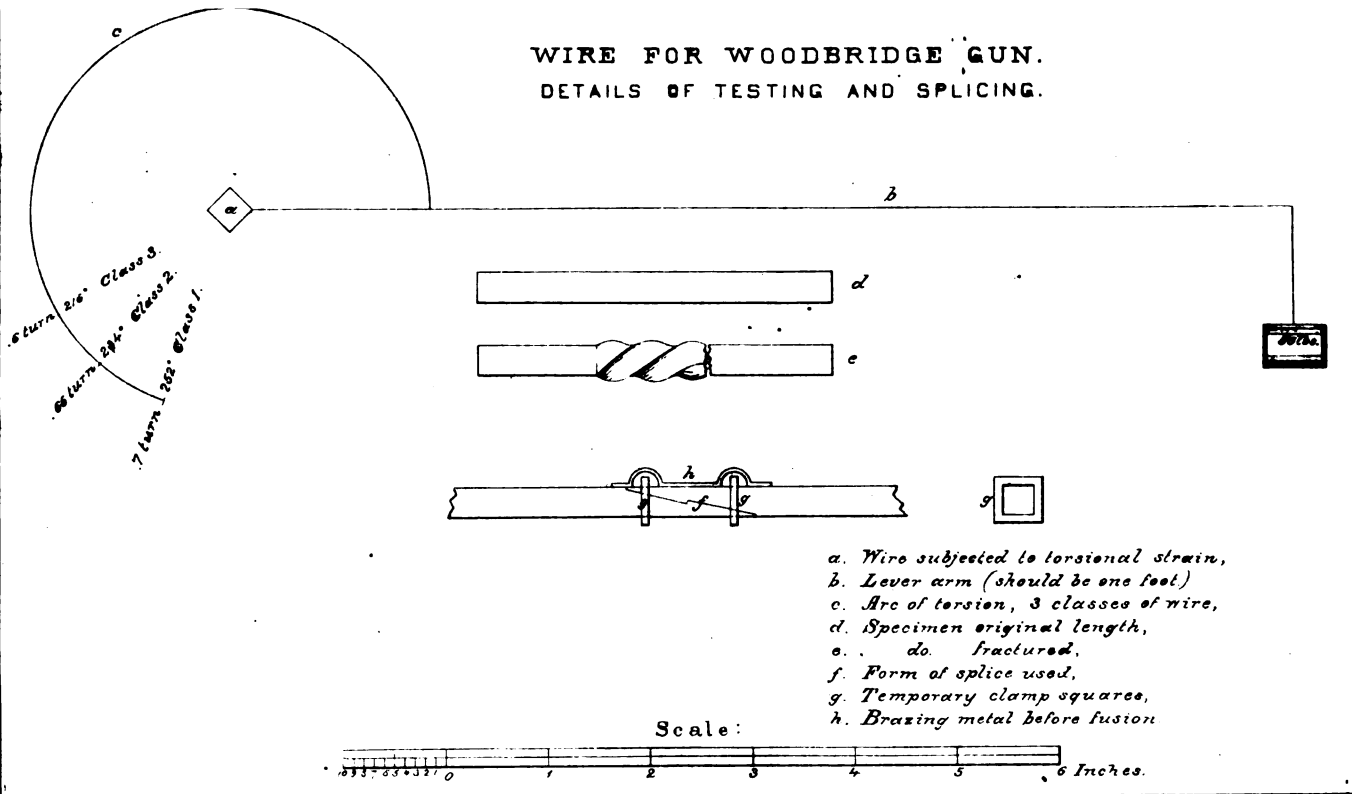
HEATING CASE AND GUN CASE OF WOODBRIDGE GUN. (9.)

ELEVATION AND PARTIAL SECTION.



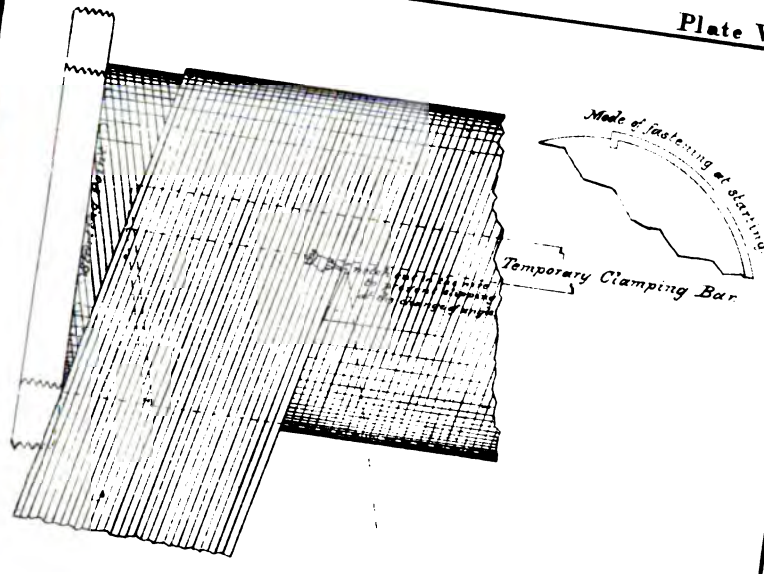
WIRE FOR WOODBRIDGE GUN.

DETAILS OF TESTING AND SPLICING.



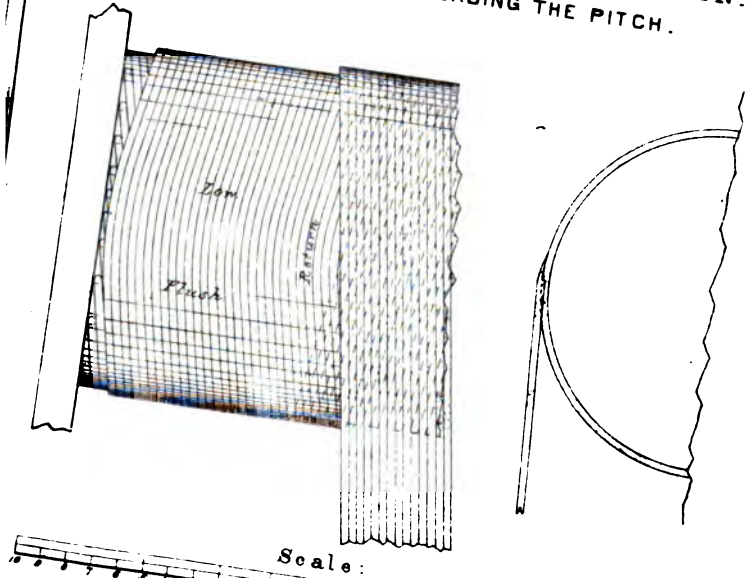
a. Wire subjected to torsional strain,
b. Lever arm (should be one foot)
c. Arc of torsion, 3 classes of wire,
d. Specimen original length,
e. . do. fractured,
f. Form of splice used,
g. Temporary clamp squares,
h. Brazing metal before fusion

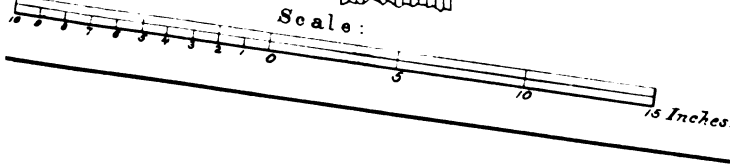
Plate VII.



WIRE WINDING OF WOODBRIDGE GUN.

DETAILS OF REVERSING THE PITCH.





WOODBRIDGE GUN.

PROPOSED PROFILE FOR FINISHING THE 9-INCH EXPERIMENTAL BLOCK
AS A 10-INCH RIFLED GUN

ACCOMPANIED LETTER OF Dr. W. OF FEB 27, 1875.

Cylindrical from a to b.

PROPOSED MODEL 10-INCH GUN.

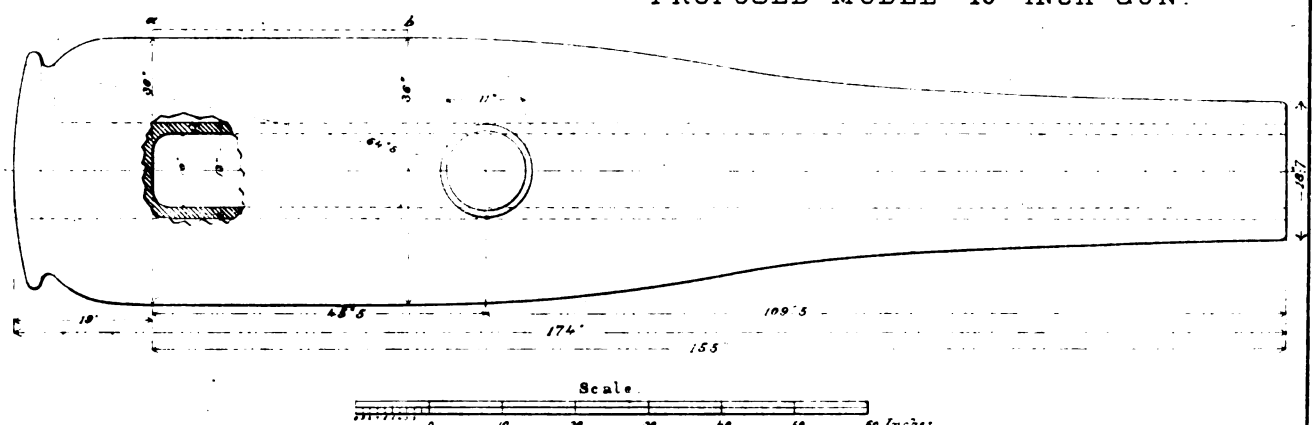
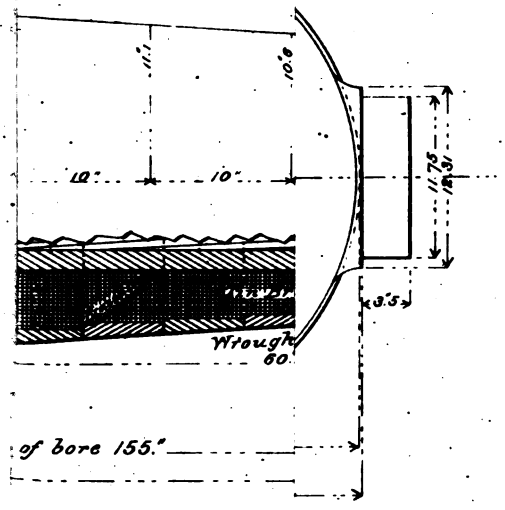


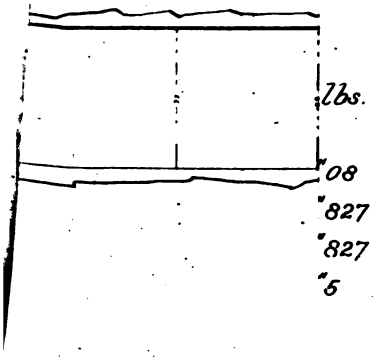
Plate IX.

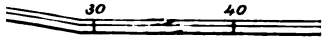
Plate. X.

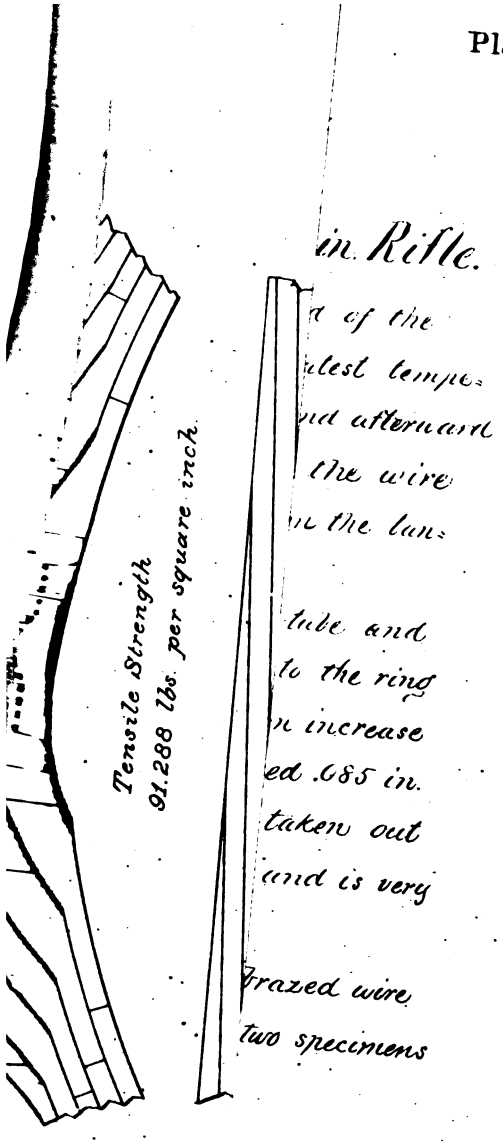
10-INCH

RSENAL, 1









in. Rifle.

a of the
ulest tempe=
nd afterward
the wire
n the lan=

tube and
to the ring
n increase
ed .085 in.
taken out
and is very

razed wire
two specimens

APPENDIX O.

Report on the manufacture of the 9-inch Hitchcock gun.

NATIONAL ARMORY,
Springfield, Mass., August 14, 1875.

SIR: Pursuant to your instructions of July 8, 1875, I have the honor to inclose herewith a report on the manufacture of the Hitchcock gun at this armory. The report comprises the following-named papers, viz:

1st. Lieutenant Metcalfe's report of a visit to Pittsburgh and Lewistown, Pa.

2d. Copies of periodical reports from this Armory describing the progress made in welding the 9-inch gun.

3d. History of the work on the "plant" and the experiments made to procure a suitable material for the gun, prepared by Captain Ramsay.

4th. Copy of Mr. Hitchcock's letter to me of the 24th June, 1875, giving his reasons for declining to proceed further with the work.

5th. Two sheets of drawings of the machinery and furnaces.

Your obedient servant,

J. G. BENTON,
Lieutenant-Colonel of Ordnance, Commanding.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

EXTRACT FROM REPORT OF LIEUT. H. METCALFE, ORDNANCE CORPS, OF A VISIT TO PITTSBURGH, PA.

NATIONAL ARMORY,
Springfield, Mass., June 15, 1875.

SIR: I have the honor to make the following report concerning my recent visit to Pittsburgh, Pa., to inform myself as to the progress made in the preparation of the material for the Hitchcock gun.

On my arrival at Pittsburgh I found that Mr. Hitchcock was absent in the East, but I called upon Messrs. Graff & Bennett, the latter of whom is the mechanical partner of the firm. He indorsed fully the practicability of Mr. Hitchcock's plan, and spoke highly of his economy in the preliminary experimental work. He stated, as one of the main reasons for the delay, the fact that some of the forging-work had been undertaken by a Mr. Miller, whose facilities were inadequate to the task.

It took some time to fully demonstrate this fact, and to allow Mr. Hitchcock to hear of and become acquainted with the facilities existing at the Lewistown works. At the time of my arrival, Graff, Bennett & Co. had sent to these works about thirty tons of their Danks iron blooms, and were waiting to hear from that place how it worked before making up any further lots. Their blooms are the largest anywhere made, and weigh about 1,000 pounds, and sometimes 1,400 pounds. In time they hope to obtain them of 2,000 pounds. The ordinary hand-puddled blooms, being limited by the strength of the puddler, weigh only 160 pounds.

From what I learned I can speak in the highest terms of Messrs. Graff, Bennett & Co.'s wise generosity in doing their utmost to facilitate the progress of this work. As an example, I may state that they

furnish Mr. Hitchcock with all the iron he needs for his experiments, and take back at its original price all that he does not finally keep. They also afford him all the advantage to be derived from their extensive technical and commercial acquaintance, and were remarkably open and polite in their intercourse with me.

The process of the manufacture of the Danks bloom is as follows:

The Danks furnace is essentially a drum about 6 feet in diameter and in length, mounted upon a horizontal axis. It rests upon friction-rollers, and is girt around by a rack into which is geared a pinion-wheel driven by a small trunk steam-engine connected with each furnace. This engine is so devised as to be very readily started and reversed, the importance of which will appear hereafter. The rear-most head of the drum is perforated for the entrance of the flame, which enters from a stationery furnace in rear of it. The front head is also open for the escape of the products of combustion, and the entrance and withdrawal of the charge. In order to convey to the chimney-stack the smoke and gas from the furnace, a movable section of chimney is hung in front of the door. This can be easily swung aside when free access to the center of the furnace is required. The interior of the furnace is plastered with a paste composed largely of powdered iron-ore, in which are set sharp angular pieces of the ore designed to thoroughly agitate the charge. The charge of pig-iron, of the composition of which I was not informed except that it was made from Lake Superior and Missouri ores, having been placed in the furnace, the chimney section is swung in front of the aperture and the drum set revolving.

The speed and the direction of the revolution are varied by the engineer in charge, so as to thoroughly expose all portions of the charge to the flame.

In about forty-five minutes the iron is melted; it then requires thirty-five minutes more before the decarbonization is complete enough for it to ball.

In order to save time it is contemplated to melt the iron in a cupola furnace, in which case the Danks furnace would be only used for puddling.

When it has come to nature, the puddle-ball, of an irregular cylindrical shape, is taken out of the furnace on a fork, on the tines of which it is rolled by a dexterous movement of the engine, and then by means of an overhead railway it is conveyed to the squeezer.

The squeezer is a double cam revolving on a horizontal axis. Beneath it are two small rolls, side by side, and about 13 inches below the lowest point attained by the surface of the cam in its revolution. These rolls form a bed for the bloom, which lies in the valley between them, and by their revolution keep it turned so as to constantly present new surfaces to the squeezer.

In the intervals between the pressure of the squeezing cams the bloom is squared up and upset lengthwise by the steam-ram. This ramming increases the diameter of the bloom and prepares it for renewed pressure by the surfaces of the cam, one of which is fluted and the other smooth. The bloom, when this operation is completed, is in the shape of a cylinder 13 inches in diameter and about 4 feet long. It contains about 30 per cent. of slag.

By building a larger squeezer, and by consolidating the product of several furnaces, blooms could be produced up to 5 tons weight. Five men run two furnaces; the leaders or puddlers for each furnace, being paid by the ton, make $4 to $5 per day. The others are mainly laborers.

To test the strength of these blooms and to ascertain their constitution, it is customary to break samples of the day's production under the hammer. I saw one so broken. It was 5 inches square, and required to break it 20 blows of a 5-ton hammer, with a fall of 5 feet, striking on a bar of cold-rolled iron 1½ inch square laid across the bloom. The bloom rested flat on the anvil. Its fracture was dark gray, slightly mottled, and of an indistinct crystalline structure. The quality of the iron seems excellent.

I was shown a ⅞-inch square bar rolled directly from the bloom, which broke at a tensile strain of 61,000 pounds per square inch, stretching 3½ inches, or 17.5 per cent., and being reduced in thickness 14 per cent., or to ¾ inch at the point of rupture. The ductility can be reduced by cold rolling.

I was shown specimens of ½-inch plate bent double cold without cracking except where it had been purposely nicked to show the long uniform fibers developed by the rupture. Also a half-inch rod tied into a knot, cold; fine specimens of holes punched near the edge of plate without cracking, and, best of all, the very thin leaves of iron, some of them are $\frac{1}{7300}$ inch thick; others have been rolled direct from the bloom even $\frac{1}{10000}$, inch thick. One very strong point in the iron is its ability to withstand extreme heat without burning or becoming brittle.

Graff, Bennett & Co. have six of these furnaces employed in their regular work, and only retain their hand-puddling furnaces for fear of strikes among the operatives, should a sudden change be made.

These furnaces have been built gradually, as their experience in iron-working developed successive improvements. For our work they would only use the one last erected. This can take about 4 heats a day—the first of which, being of inferior quality, is generally employed in making merchantable iron of low grade. They could make all the blooms necessary for the 9-inch gun in two or three weeks' time, as soon as Mr. Hitchcock determines to give the necessary order. This he delays in order to give them all the time possible to improve their stock, while he is settling the preliminary questions regarding the steel centers for the elementary disks or "cheeses," and also because he is confident that they will be able at any time to keep the Lewistown hammer supplied with blooms, if the experiments which he is making from time to time should require any change to be made in their manufacture. Otherwise they might make up a lot which would have to be thrown away.

At the Sligo Works, Pittsburgh, H. McDonald, superintendent, the manufacture of the core or lining of low steel is as follows: A hand-puddling furnace is charged with No. 2 cold-blast charcoal, cast in iron molds. It has a beautiful white fracture near the edges, growing dark toward the center. At a certain stage of the proceeding the puddler casts into the furnace a lump of physic, as it is called, the composition of which is secret. There is an instantaneous change in the character of the flame, and the puddle-ball soon comes to nature.

Being removed from the furnace it is carried on an overhead railway to the hammer, and there forged into a cylindrical shape. It is in the furnace for about an hour. The largest unit manageable weighs about 400 pounds. The excess of this weight over that allowed for ordinary hand-puddling is probably due to the "doctoring" relieving the puddlers of much of the work of decarbonization. Two pair of these units, weighing about 1,600 pounds, can be combined under the hammer. They would finish at about 1,400 pounds.

The furnace is a gas-furnace containing a reverberatory chamber

separated by a bridge wall from a pocket at one end containing bitum nous slack coal, the slow combustion of which supplies the gas. Aft having done its work, the flame on its exit passes over water, in ord to save the smoke-stack from burning.

A better plan than this was seen at Graff & Bennett's, where t waste heat was passed through the flues of a vertical boiler surroun ing the stack.

The history of Mr. Hitchcock's connection with the firm of Gr Bennett & Co. is as follows: On Mr. Hitchcock's arrival in Pittsbur his idea was to make his disks of bar-iron, piled and welded, and work into concentric rings with a tire-rolling machine. At this time he fou the firm, who for a year past had been engaged in the manufacture the Danks iron. Their product then, while good enough for tr orders, did not seem well fitted for use in gun-construction, owing its fibrous nature. The idea being, that in hammering a fibrous blo to condense it, the fibers would cross and cut one another, as in ha mering on a string, and the mass would either fall to pieces on the an or would appear when broken afterward like a compacted ball of l dry clay. Their object was to get the bloom granular in the first pla so that the hammering would draw the crystals out into the form fibers. By constant experiment they discovered the means of do this about three months ago, and since have turned out the desi material with great uniformity. I may observe that they are working to improve this by attempting to carbonize the bloom in furnace, so as to convert it into low steel. They occasionally succ in getting portions of a bloom, and, more rarely, an entire bloom of material, but the product is too uncertain to be depended upon.

Besides the extra strength and hardness which this material wo assure the gun if it could be turned out in large and uniform quantit we should derive the further advantage of having only one kind of m to heat in welding, and so avoid the complications caused by possi different welding temperatures for the iron body of the gun and its s core. Also the responsibility for material would be undivided.*

To return to the Danks iron bloom. Owing to the small size of Graff & Bennett hammer—it weighs only 5 tons—they were unable hammer the blooms themselves sufficiently to fully express the cin

After a while Mr. Hitchcock heard of a very large hammer at Logan Iron and Steel Works, Lewistown, Pa., of which Mr. Brosiu superintendent. It is a 10-ton hammer, with a fall of 11 feet, and w ing with 100 pounds of steam on both sides of a 36-inch piston. is believed to be the largest steam-hammer in the United States, tho possibly one at Nashua, N. H., may be as large.

As soon as this hammer was discovered it was set to work, and at time of my visit had completed a forging which looked very well. T had welded a puddled steel core into each of two pair of Graff & B nett's rings; and, by welding these two rings together, made a p weighing about 2,700 pounds, which is to be bored, turned, and sl up to examine the welds.

I visited these works and met there Mr. Brosius, the superintend He spoke approvingly of Mr. Hitchcock's plan, and anticipated trouble in doing his part of the work, provided he had sufficient tim make the alterations in his minor tools and furnaces necessary for s heavy work. He also praised highly the Danks iron. The only th he feared at all were the possibility of the large trunnion piece, 52 in

* JUNE, 1875.—I have just been informed that they can now turn out this terial with absolute certainty, and of unvarying quality.—H. M.

in diameter, not having strength to support itself when hot; and also that it would be a difficult matter to weld together the steel cores. He thinks he can do the preliminary forging for two or three of these guns in sixty days, if necessary, at a cost of about 4 @ 5 cents per pound.

I here give a description of the method of working the Danks bloom into the elementary parts of the gun.

Danks bloom, just as it ordinarily comes from the squeezer under present system: weight, 1,000 pounds; contains 25 to 30 per cent. slag. Compressed by ramming it a good deal more than usual in the squeezer; by so doing a great part of the slag is expressed, and the column is shortened without increasing its diameter in consequence of the continued revolution of the cam. This makes the column less liable to cripple when flattened under the hammer. In this stage it leaves Pittsburgh for Lewistown.

The steam-hammer soon pounds it down to a thickness of about 12 inches, depending on the position which the piece will occupy in the gun.

It is reversed frequently on the anvil in this operation, so as to upset both ends equally. It is then returned to the furnace and brought to a "soaking heat," then hammered to a 12-inch square bar, so long as the amount of material will permit. The "porter-bar" of Swedish iron, which is welded to the block, serves to handle it when under the hammer. The hammer-man continues to draw out and upset this piece alternately, until the cinder is as well expressed as the heat will permit. The original bloom is thus reduced to 500 or 700 pounds weight.

The block is then brought again to a welding or soaking heat. It is then replaced on the anvil, standing on its small end, and is driven down one-third of its length, say from 18 inches to 12 inches. By the aid of the porter-bar, it is turned on its corners and patted into a roughly octagonal form. It is then worked back and forth, reversing it occasionally till it assumes a rounded shape, caused by the bulging of the ends, which receive the greater part of the hammering. The hammer-man then cuts off the porter-bar and returns the disk to the furnace, where it receives another soaking heat. It is then replaced on the anvil and driven down to about 10 inches, then punched with a conical punch 7 inches in diameter, which is driven through by the hammer, point foremost. The punch is lifted out of its bed, the disk turned over on the anvil, and the punch set in from the other side. This time it goes clear through, driving out a piece of waste stock weighing only about 2 pounds. This hole is intended for convenience of manipulation; it also serves to condense the metal.

A conical mandrel on the end of a long shaft is then inserted into the hole just punched. The disk is balanced by men hanging on at the further end of the shaft, which is suspended mid-length by a chain. The disk is set edgewise on the anvil and lightly hammered into a circular shape. A friction-roll against which it rests helps it to turn under the blows of the hammer, a man lifting the disk toward the friction-roll with a pinch-bar meanwhile. The friction-roll also serves as a stop for the disk. The disk is then laid flat and driven down to 4 inches in thickness. Its diameter is then about 32 inches; this necessarily contracts the hole. The disk is then hammered slightly crowning on one face. Two of these pieces are laid up cold in a furnace, being kept apart by three cubical blocks of wrought iron one inch on the edge. These blocks permit the flame to play between the two pieces, and also keep the pieces from touching on the edge first when they are brought under the hammer for welding. They are brought to a welding heat, taken out with a fork

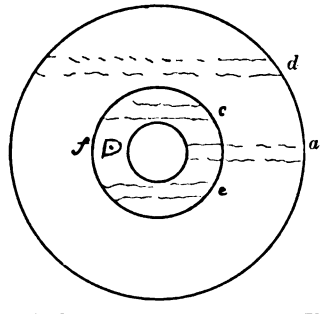
and welded. In bringing them to the proper heat, the iron and slag can be seen running down like icicles.

After welding, the disks are repunched up to 12 inches; a low steel plug, 12 inches in diameter and 2 inches longer than the thickness of the double disk, is brought to a welding heat at the same time with the double disk. The latter is then laid upon the anvil, the plug inserted and driven home. By hammering, its ends spread and rivet the disks together, securing them thus in addition to the weld. They are then punched again up to 7 inches.*

EXAMINATION OF EXPERIMENTAL FORGING AT FORT PITT FOUNDRY.

The piece examined was made as above described. It weighed 2,700 pounds, was 9¼ inches thick, and 38 inches in diameter. The steel core was flattened out on its face to 15 inches. It was about 1¼ inches eccentric on the outer edge. Near the edge of the hole there were two slight radial cracks about one inch deep and running up the bore for about the same distance. The difference in color and in hardness between the iron and steel was plainly discernible.

In boring out the disk a check, seemingly only on the surface, was discovered about half an inch in from the muzzle. By continued boring this was found to extend first downward and then around the bore at ¾ inch from the muzzle. There it ran for about 5 inches in a shallow groove about $\frac{1}{10}$ inch wide and half as deep. It was continued to enlarge the bore, the flaw growing smaller and smaller until the caliber was 9⅝ inches. The flaw had not then disappeared. I then assembled Mr. McDonald, the steel-maker; Mr. Williams, Graff & Bennett's superintendent; and Mr. Hitchcock. They thought respectively that it came from underheating or overheating the steel; from a "slip" in the original puddle-ball, in which, from its irregular shape, a lap or cold shut might be formed inclosing a certain amount of slag. Mr. Williams stated that in the Danks bloom, from its shape, this would be unlikely to occur. Mr. Hitchcock thought the piece burst inside in flattening the corners of the square piece in which it was first forged, (12″×12″×8″.) The piece was re-examined when removed from the lathe for slicing. The union of the steel cores seemed perfect. The rearmost portion of the bar was honeycombed and pitted evidently from the cause producing the flaw.



Mr. Hitchcock continued to cut up this forging after my departure and made test specimens from the pieces. He tried them with the following results:

* *June*, 1875.—This has lately been done, as follows: To avoid the checking likely to result from forging the plug solid, the steel centers are first forged cylindrical, as before described, and punched nearly to size. They are then turned inside and out and united substantially as above described. This course enables the manufacturer to discover defects in time to avoid incorporating them with other good work. (See experiments on experimental forging at Fort Pitt foundry, further on.)

Two double pieces are laid up as described and welded. They are then hammered down to about one-half their original thickness and punched again to a 7-inch hole. In this case the punch is inverted so as to cut a clean hole with its square edge inserted, merely spreading the metal. The metal now takes the form which may be considered one of the units of construction for the gun in its forging at Springfield. It first, however, has to be turned and faced off to a convex surface, after having been mandreled and finish-hammered on the rim.

	Pounds
a. Steel and iron broke in weld	30,000
b. Steel and iron broke in weld	38,000
c. One piece steel	42,500
d. Iron	47,000
e. One piece steel	47,000
f. Steel across weld	40,800

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Very respectfully, your obedient servant,

HENRY METCALFE,
Lieutenant of Ordnance.

Lieut. Col. J. G. BENTON,
Commanding.

PERIODICAL REPORTS ON THE CONSTRUCTION OF THE EXPERIMENTAL HITCHCOCK WROUGHT-IRON 9-INCH GUN, MADE BY OFFICERS OF THE ORDNANCE DEPARTMENT STATIONED AT THE NATIONAL ARMORY TO THE COMMANDING OFFICER THEREOF, LIEUT. COL. J. G. BENTON.

BY FIRST LIEUT. HENRY METCALFE, 1875.

April 5.—*Lathe.*—Turning off face of defective disk to cut out bad spot in forging and reducing diameter 4½ inches to finish-size. This one of the small pieces, No. 5, from the muzzle.

Furnaces.—Heated up to dry brick-work thoroughly. They draw well; the blast is amply strong. George Ormsby, the heater, arrived from Lewistown to-day. Began work on a grapple-iron to hold disks in transfer. Mr. Hitchcock handed in list of helpers wanted.

April 6.—*Lathe.*—Still turning small ring; trying different plans of shifting hooks; furnaces work well; heat uniform and intense; helpers informed; three declined work. Started to gauge supply of water required for hollow water-bottom (hearth) in heating-furnace, by closing valves in pipe leading from main tank to distributing-tank to prevent leakage, and thus to see how much pumping would be required to fill up main tank during the night, if distributing-tank should not be large enough to supply the water-bottom during that interval.

(See note.)

Ordered to allow no visitors without special pass.

April 7.—Waste from water-bottom examined at 10 a. m., and water found running out all right. Examined at 11.45, found exhaust-valve closed. (This caused heat to form steam in water-bottom and drive water back into tank through supply-pipe, leaving water-bottom empty.) In the excitement of this discovery Mr. Hitchcock (so says Roberts, foreman of the work on the gun) opened this valve, thus relieving steam-pressure and allowing cold water to pour down into the water-bottom. This cracked it.

It was impossible to determine who shut the exhaust-valve. It was in a retired corner, under the platform, where the work is mainly done.

Mr. Hitchcock proposes to make a false bottom of sand for present experimental use, with the hope that the water-bottom may not be found essential.

The grapples are approximately centered by a gauge fitted to disk when cold, and any variation in level corrected by a bar attached to the disk.

Continued turning off disks to finish-size. Forging large spanner to turn anvil-blocks, &c., resting on hydraulic piston.

First trial: The iron, 3 inches square, was so poor that it burnt up in the furnace.

Mr. Hitchcock expects daily a letter from Fort Pitt foundry, informing him that a man has been sent familiar with the 20-inch lathe, to set up the trunnion-lathe, &c., or else inclosing drawings or information to assist him in doing so himself. The lathe is of peculiar construction, and he does not think it expedient to hire a man from South Boston or elsewhere, who might insist on reconstructing it. As soon as experimental forging is over he will overhaul it himself.

April 8.—Furnaces kept at a high heat all day long to "fix" or solidify their sand-hearths, especially false hearth over water-bottom.

Consultation as to best method of transferring disks, turning them in furnaces, &c., &c.

Putting patch on steam-boiler designed to supply hammer-cylinder.

April 9.—Freeing inlet-valve of hammer-cylinder, and welding up spanner. Repacking steam-cylinder.

A rope is to be led from the eye in the spanner and a bight taken around main arbor of the 20-inch lathe, so that by its revolution in ordinary work it will haul the spanner around and thus turn the pile of anvil-blocks supporting the disk which is heating in the furnace above. The object of this is plainly to heat the disk uniformly throughout.

The anvil-blocks have holes in their peripheries in which pins are fitted as points of attachment for the spanner. Cleaned out cylinder by blowing steam through it. Placed one experimental piece in hammer-furnace, and covered it with sand, to protect it from the fire until we were ready for welding. This was done to save time and as a drill for the helpers.

April 10, 1.45 *p. m.*—One of the experimental disks placed in heating-furnace at 1.45. The other disk uncovered at the same time. Turning anvil on its own axis most successfully practiced. One man doing all the work except in changing spanner to a new set of holes. Heat of disks determined from time to time, by trying to pull off a piece with a hand-hook.

3.15 *p. m.*, tried to revolve piece in heating-furnace through the door with a wrench-shaped tool. The piece stuck on the hearth and the gas-pipe handle grew soft by the heat and bent. This mode of proceeding was necessary on account of the failure of the water-bottom. On account of which, also, the base of this piece was surrounded by broken brick to keep it as cool as possible, so that in welding the blow of the hammer would not distort it unnecessarily.

3.16 *p. m.*, the cross-pin at the upper end of the hammer-shaft is taken out and the hammer is resting on the steam alone. Tension about 60 pounds per square inch.

3.18 *p. m.*, hammer accidentally dropped on the furnace-lid crane, which was standing directly under it; Mr. Hitchcock at the throttle. The fall of three inches sprung the mast of the crane, a piece 12-inch or 14-inch oak timber, out about 2 inches, but it did no perceptible injury.

3.21 *p. m.*, began dragging out bricks from about bottom of piece in heating-furnace.

3.22 *p. m.*, piece taken from heating-furnace by fastening on it with a hand-hook pulled by six or eight men.

3.22½ *p. m*, seized by grapples without the slightest difficulty at the extremities of a diameter below the center of gravity, so that its own weight caused it to revolve in the hooks, bringing the hot side down. It required no adjustment, but was practically level. The lid is simultaneously swung from the hole in the hammer-furnace. The cast-iron center is inserted into the hole of the lower piece to guide the upper one to a horizontal and central position.

N. B.—The square hole in the center is intended for a wrench, by hich to break it up after its duty has been performed.

The center enters with difficulty; it does not stand upright, but tips ı one side or the other, growing hot meanwhile. It acts as if too large ır the hole. Three cubical blocks of iron, about 1 inch on the edge, :e thrown on the surface of the lower disk, to keep the two from touch- ıg and sticking and allow a lateral adjustment by ramming to center ıem.

3.25 *p. m.*, the top piece, heretofore held suspended in the hammer- ırnace, is lowered; it strikes one corner of the cast-iron center, melts ıe corner, and topples the piece over, so that it rests off to one side on vo of the cubical blocks and on its edge.

3.28 *p. m.* Fortunately by this time it is too cold to stick, so that it pried off and freed.

3.35 *p. m.* After consultation, it is decided to draw the fires, cool off, ıd begin again Monday. Upon reflection it is found that the trouble due to the sand with which the lower piece was covered having fallen ıto the bore of this piece and filled it up, so that the center rested upon ıe sand, instead of on the edges of the hole. By this time the upper iece had grown too hot to hammer, so that, even if the sand could have een removed from the hole, the piece would have had to have been rst cooled and then reheated, for which there was no time.

Mr. Hitchcock decides that a water-bottom is essential, and telegraphs ıis evening to Buffalo to proceed making a new one immediately. He lso telegraphs to Fort Pitt foundry to hasten action about men re- uired to set up lathe.

Explanation of water-bottom.—It is a hollow annular piece of cast iron, ightly larger than the largest disk, which forms the bed upon which ıe disks are to rest in the heating-furnace. It is connected with the ater-service, so that a constant stream of water flows through it to eep the bottom of the piece resting upon it from becoming too hot. It ı covered with a few inches of sand. Through the hole in its middle ıns a vertical rod downward through the floor, which, in combination ith a powerful lever, raises the disk slightly from the hearth, to allow ; to be easily revolved in heating.

The men did their duty well. They did not shrink from the hot iron, ut handled the pieces with great unanimity and courage. The trans- ɜr was executed with surprising celerity.

April 12.—Mr. Hitchcock has decided to revoke his order for a new ast-iron water-bottom, and has accordingly done so and removed the ld bottom, with the intention of strengthening it by shrinking on a oop of heavy bar-iron. On removal, two fine cracks were found, one inches and the other 8 inches long, running radially from the central ole. The bar was heated in the hammer-furnace, wrapped around the ater-bottom, welded, and shrunk on, and the water-bottom replaced in he furnace by 6 p. m. Fire was immediately started for the next day's ork. In order to indicate "low water" in the water-bottom, it was onnected with a basin outside, by the inspection of which at any mo- ıent, and by observing the temperature of the overflow, a deficiency ould be at once discovered.

The exhaust from the water-bottom has two branches, the upper one ɔr air, the lower one for water. The office of this one is not so appar- nt. The hoop was shrunk on beneath the arms of the bottom.

April 13.—Mr Hitchcock devised a new tool for opening and manag- ıg the transfer-grapples.

Men drilled in handling disks as follows: The diameter-gauge is set

when the disk is cold. When supposed to be hot it is again applied, the grapples are brought up by their crane, they are guided by the opener, which hangs on an independent chain on the same crane as the grapples and a little behind them. By depressing the farther end the grapples are opened and then dropped down on the sides of the disk until the pins on their ends strike the floor; this brings their teeth at the extremities of a diameter just below the center of gravity. The opener is then removed and the grapples steadied in place by long hooks held by the attendants, while the chain supporting the grapples is tightened by another gang at the windlass of the crane.

9.45 *a. m.*—Both pieces were in heating at 9.45 a. m.; both pieces being turned by hand; the top piece on the water-bottom in the heating-furnace being revolved. A chamber beneath the furnace is kept sufficiently cool by the water-bottom for a man to be able occasionally to go there and by means of the lever to raise the disk clear of the water-bottom on which it rests. By means of the wrench, the piece is revolved by hand slightly, and then dropped again on the water-bottom. The short end of lever forms a step in which the pointed end of the vertical bar revolves. Its upper extremity is provided with a large conical center to fit the hole in the disk. It is kept upright by suitable guides.

11.38 *a. m.*, opened door of heating-furnace.

11.38½ *a. m.*, encircled disk with a hoop bent on the end of a long rod.

11.38¾ *a. m.*, out of heating-furnace, on platform.

11.39 *a. m.*, grapples on; the disk turned over well, but was not quite level.

11.39¼ *a. m.*, hammer-furnace lid off and cast-iron center in lower piece.

11.39½ *a. m.*, top piece lowered. Owing to its tilting, there was some danger of its sticking on the edge if it touched there first. In the delay caused by the fear of this, and the additional difficulty in centering, the piece cooled slightly, so after centering it carefully so that the two surfaces were only about two inches apart, at

11.41 *a. m.* the grapples were removed, and at—

11.42¼ *a. m.* the cover was put on the hole.

The two pieces were now allowed to heat together until—

11.43½ *a. m.*, when the cover was taken off, and the first blow with the hammer struck at—

11.45½ *a. m.*, only 5½ minutes from the opening of the furnace-door, including the time of the second heat, the hammer-shaft was dry from the heat beneath it, so that it stuck somewhat and had to be worked up and down several times to free it. It thus struck in all 23 blows, of greater or less force, though three or four blows were sufficient for the welding.

11.48 *a. m.*, cover put on again.

11.50 *a. m.*, cover off.

11.50¼ *a. m.*, hauling on punch-chains.

11.52½ *a. m.*, punch set in hole; the chains got stuck in the pulleys; were freed 11.53½ a. m.

11.53¾ *a. m.*, hammer down.

11.54 *a. m.*, punch removed.

The object of this punching is to render the mouth of the hole conical, to form a seat for the next cast-iron center. It was then thought of to remove the center used in the welding by twisting it apart with a wrench, but it was, at

11.56 *a. m.*, found melted.

In the afternoon another disk was to be welded upon that already

tried, but just as the piece was about to be taken from the heating-furnace, the water-bottom burst again, deluging the furnace and filling the place with clouds of steam. No other harm was done.

Mr. Hitchcock goes to work immediately on a wrought-iron water-bottom, the rim of which will presumably be a locomotive tire 5½ feet to 6 feet in diameter. He is convinced of its necessity.

The forgings of this morning, on being removed, looked well. The eccentricity was not over ⅛ inch; no deformation on account of the hammer; the edges of the weld clear and close all around.

I was here taken sick, and have since been unable to attend to the work.

BY FIRST LIEUTENANT JAMES ROCKWELL, JR., APRIL 17, 1875.

The water-bottom of the furnace for heating the disks or cheeses having broken upon the previous day, Mr. Hitchcock resolved to heat the disks in the furnace where the welding and hammering are done. The cheese or disk which forms the bottom of the breech was heated in this furnace, and the thin disk which is intended to complete the breech and furnish the ratchet-holes was swung into the furnace by a temporary arrangement of iron tongs or chains, much more awkward to manage than his original crane and windlass. The furnace was again closed, and the two disks exposed to what he judged the proper degree of heat, being properly centered with reference to each other. After heating for over an hour, the top of the furnace was removed and the hammer dropped some twenty times upon the disks. During all this time a block or cube, designed to afford a bearing-point for the base of the gun in its subsequent turning to the proper shape, had been placed in the front of the furnace so that its base might be properly heated. This was now swung into the furnace, a dowel having been placed upon the surface of the thin disk mentioned, which should fit into a dowel-hole in the bottom of the block, and thus insure the proper position of the block upon the disk.

The furnace being again closed, the block was heated to the proper point and hammered as the disk had been. It will be observed that in attempting to weld together the two disks a cold surface had been brought in contact with a heated one, while in welding the block to the thin disk, two heated surfaces were brought together. On removing the block and disks from the furnace, the block and thin disk were found to be firmly welded together, but there was no weld with the other disk. The heater employed by Mr. Hitchcock was obliged to return to his home the same evening, which prevented a renewal of Mr. Hitchcock's experiments.

Mr. Hitchcock's intention now is to cup the base of the steam-hammer by turning, using the lathe employed in turning the disks. The object of this is to give a convex surface to the disks, and thus squeeze the cinder from the center to the outside of the surfaces welded together.

BY FIRST LIEUTENANT HENRY METCALFE.

My absence on duty at Lexington, Mass., on the 19th and 20th prevented my taking any notes upon those days, but nothing of moment was done meanwhile, except the first stages of the work whose completion is noted hereafter.

April 21.—Work on new boiler-plate water-bottom continued; drilling holes in rim and punching and countersinking rivet-holes in head;

construction of temporary forge for heating rivets; turning off face of hammer to a concave surface, in order to render the upper surface of the *last* disk forged convex and thus promote the radial expression of cinder in welding.

April 22 *and* 23.—Commenced riveting water-bottom at 8 a. m.; finished at 2 p. m. This is quick work, considering that there were about 150 rivets to head and clean off. The water-bottom, as it now stands, consists of an old steel railroad tire, 6 feet diameter, 1½ inch thick. The two heads are made of iron boiler-plate ⅜ inch thick, secured to the tire by 100 rivets running through its entire thickness 6¼ inches. In the middle of these a 20-inch hole is cut, around the edges of which the heads are riveted to a smaller circle corresponding to the tire outside.

Between the heads are 12 spiral wings, designed to support the weight of the disk to be heated, and 24 stay-bolts riveted through both heads and surrounded by sections of gas-pipe designed still further to stay the heads.

The inner circle is fluted longitudinally between the rivets to allow the water to approach its inner surface.

One section, the further one, of the boring-bar was rigged up on the lathe.

The head of the hammer was replaced on the hammer-shaft. The inlet and outlet pipes of the water-bottom are arranged now so as to keep the water-bottom always full. In the old cast-iron one, there was a space of ¾ inch on top of the water.

The lathe is employed in turning off the thin piece to which the cubical sprue is welded, so as to reduce its diameter 3 inches. This will then be welded to the base-piece of the gun.

When welded, both pieces will be removed to the lathe and a circular neck cut in the cubical piece about its junction with the second piece. The pile is then inverted and returned to the furnace, and the rest of the gun built up on it. When finished and placed in the lathe, the weight of this end of the gun rests upon a bearing beneath this circular neck, while the square portion of the piece affords a sure means of revolving the gun in the lathe by means of a square recess in the face-plate.

For this preliminary forging the heater is expected to arrive on Tuesday next.

April 24.—The water-bottom was tightly calked and replaced in the heating furnace.

BY FIRST LIEUTENANT JAMES ROCKWELL, JR., APRIL 30, 1875.

In my report of the 17th instant, the operations of the 14th instant were described. The object of yesterday's (April 29th) operations was to complete the work which partially failed on the 14th instant. The disk and block which were at that time welded were placed with the disk uppermost in the heating-furnace and heated for nearly four hours. While the disk and block were in a nearly pasty condition, a small block of wrought iron was heated and tamped, by means of an iron bar, into the center of the disk; the object of this, as I understand it, being to cover some slight flaws in the disk, and also to dowell or dovetail this disk to the next one when the hammering and welding should take place.

During all this time the large disk, to which the block and disk were to be welded, had been heating in the welding-furnace. The block and disk were now removed from the heating-furnace by means of the tongs and long-handled iron hoop, turned over and swung into the welding-furnace with the block uppermost and the disk resting upon four small

blocks of iron placed upon the large disk. The block and disk were thus kept about 2 inches above the large disk, allowing the heat to act upon the lower surface of the small disk. The cover of the welding-furnace being swung on, the block and disk were heated about twenty minutes, then revolved half way round, and about twenty-five minutes later the furnace-cover again removed, when the hammer was repeatedly dropped upon the block and disks. There was a considerable escape of steam from the joints of pipe of the hammer, which condensing, caused a constant dripping of water. The hammer did not work easily, the reason assigned by Mr. Hitchcock being that it is used so seldom and for such short periods, a defect which he expects will cease as soon as the regular work upon the gun proper commences. A little more than two hours after the hammering the block and disks were removed, by means of chains, from the furnace and the cooling completed. The disks had slightly fused on the side longest exposed to direct heat, and the block was badly cracked and fused. Mr. Hitchcock stated that the disks had been too long heated on the side melted and that the block was of inferior iron.* The surfaces were well welded together, and the experiment was quite successful. The fire in the furnace was extinguished, and the operations for the day were ended.

BY FIRST LIEUT. HENRY METCALFE.

April 26.—Spent in bricking up near water-bottom and in making its connections with water-service. Cut off supplementary piece (B) between cubical sprue and bottom piece of gun.

April 27 *and* 28.—Brick-work on furnaces repaired and preparations made for welding next day.

April 29.—Welding supplementary piece to bottom piece. (See Lieutenant Rockwell's report.)

April 30.—The fires were started at about 4 a. m. In the hammer-furnace were the two pieces welded April 9 sunken, so that the top surface of the uppermost and smallest piece was just level with the floor of the furnace.

In taking out the third piece of the pile from the heating-furnace it tipped over, and got so cool that it had to be returned to the furnace and reheated. In taking it out again it was well held by the tongs, but about three minutes were required to put it in place. It was allowed to heat for about one-half hour in the hammer-furnace and was then welded, taking three blows of the hammer, one of which was by accident of about 3 feet fall. Mr. Hitchcock was at the throttle. The weld looked well and no great distortion was observable. The cast-iron center worked well on this occasion, though the small cubical blocks, before referred to, were also employed. This course was followed throughout the weldings

In taking out the fourth piece the tongs slipped off before it was fully centered, on account of its tipping and striking on one edge upon the piece below it. This took the weight off the tongs and caused them to relax their hold.

The piece was approximately centered and pried into place with bars. It was welded with nine blows, taking three minutes from the time the cover was taken off until it was replaced, including welding and punching.

*NOTE.—The turning of the gun will remove the slight portions of the disks which were melted, and the block is still perfectly serviceable for use as a screw-head in turning, as it is to be considerably reduced in size before placing it in the turning-lathe.

The fifth piece was placed without difficulty and welded with ease. In punching it with the taper-drift the drift was set in somewhat one-sided. In punching it again for the cast-iron center the hole was made somewhat too large, so that the center had to be supported by a fire-brick placed in the bore.

In putting the sixth piece into the heating-furnace it is supposed that it dropped a short distance upon the water-bottom and set it leaking.

In consequence, when taken out, the bottom was black and the top at almost a white heat. It took 4½ minutes to get it in place, having to be steadied and worked on with bars. The lid was put on and a heat taken for about three-quarters of an hour, at which time the piece was easily welded with four light blows.

May 1.—The pile of pieces was removed from the furnace, and presented very much the appearance shown in the sketch. The welds were cut with chisels, &c., and appeared sound. I would propose to test this pile by putting a heavy screw into each end of the bore, one screw having a hole, say one-quarter of an inch, through it for a vent, and then explode various charges of powder, increasing in weight until the pile should burst or tear apart.

May 3 *and* 4.—The large lathe was employed in turning the sprue-head into workable shape. It is so deformed by its exposure to the heat and the crushing blow which it received that its finished size will be materially diminished. The texture of the iron is poor, spawling off in advance of and to one side of the cutting-tool. This is, of course, only material in showing the effect upon poor iron of a disintegrating heat.

The bulged and leaky water-bottom is being repaired by putting in new rivets in place of leaky ones and strengthening it by new stay-bolts, in the manner originally suggested by the boiler-maker employed. The surface of the water-bottom is bulged and blistered very badly, and I hardly think can be made absolutely tight.

The fire-brick masonry of the heating-furnace is being built around the hole through which the anvil passes. Mr. Hitchcock's great fear was that the flame might be drawn down through the opening between the sides of the anvil and those of the hole. In his experiments he consequently laid a loose course of bricks around the circumference and projecting over. These became detached and fell through the opening, causing considerable annoyance and danger to those working below, and showing that there was no necessity for any such provision.

May 5.—In turning up the large bottom piece with the sprue welded to it, it could be seen where the cubical 2-inch blocks, introduced to support it in the final heat, had failed to become incorporated in the mass. Nothing serious was inferred from this, however, as their presence was probably betrayed by the thin piece above them curling up when struck. The six-piece forging made last week was smoothed off between two welds for a flat surface 1½ inches wide and about 4 inches long, and etched. No sign whatever was shown of the weld, even after the acid had been on for two hours.

May 6.—The experimental forging was placed in one of the shop lathes and turned exteriorly. Its appearance, as far as the welds go, is excellent. It will finish off about 19 inches exterior diameter. It is about 3.5 feet long. Its finished caliber can only be determined after its exterior dimensions are fixed.

At work on water-bottom, masonry for furnaces, bottom piece as before. Since the completion of the furnaces there have been expended of Cumberland coal as follows: 8,000 pounds in drying-furnaces, fixing them, &c; 79,150 pounds in welding.

The last item includes 18,000 pounds for the last heat, 5 joints, 20 hours; 15,000 pounds of the above were used for steam, at the rate of about 1½ tons a day.

May 8.—Continued same operations. Experimental forging looks well. One of the disks is steely in spots. It is thought that the work on water-bottom, sprue-head, and new centering pieces, made of wrought iron, will be completed so that the work on the gun will begin by about the 20th instant.

May 10.—In continuing the turning of the experimental forging the workman found four places in the welds where the chips would of themselves split in two longitudinally when the cutting-tool happened to include both sides of the weld. This would indicate a defective union of the two pieces.

Unfortunately, the general obliquity of the column causes the circle of the cutting-tool to cross the welds at an angle, and so the extent of the trouble cannot be fully determined. It is found, however, where about 3 inches of the material has been cut away on one side. I submit herewith such a chip, showing the false weld. It looks better as the cut approaches the center, but still shows, looking like a heavy black pencil-mark running irregularly along the oblique shoulder left by the cutting-tool. The second joint from the bottom of the pile, where this trouble has not been found, has not yet been turned.

The cascable piece has been placed in a planer to be squared up.

The large lathe is occupied in turning a 14-inch hole in a cast-iron anvil-block to admit the cascable when the bottom piece is placed in position. The repairs on the water-bottom were practically finished to-day.

May 11 *and* 12.—Mr. Hitchcock believes that the imperfections in welding came from clay dropping from the roof of the furnace, or, more probably, from the melting of the cast-iron centers and the flowing of the molten iron between the surfaces to be joined. To remedy this, he has devised a wrought-iron center, made of two hoops of round iron, fastened together in a somewhat ovoidal shape. These will stand the fire much better than the cast-iron ones, and can be drawn out from above when sufficiently softened by the heat. They also afford a chance for looking through the space between the two disks when in position.

May 13.—In turning off the outside of the experimental forging, a chip was removed at the junctions of the second and third pieces which was not welded. This piece was about 3 inches beneath the surface.

At this juncture you decided to prove the forging with powder, and consequently no more turning was done on the outside. But it was removed to a boring-lathe in order to fit screw-plugs into the ends.

The large lathe was occupied in cutting a hole through an anvil-block for the cascable-block to rest on. The cascable-block was removed to a planer in order to square up the cascable.

Mr. Hitchcock left for Pittsburgh to-day in order to make further experiments with the iron.

May 14.—Large lathe turning up a spare piece of iron for the gun. Workmen cutting another door in welding-furnace, through which to guide disk in welding it.

May 15.—It took three men nearly all day to cut out with bars and chisels the rough sand, scoriæ, melted cast-iron, brick, &c., from the experimental forging. The hole is tolerably smooth, but quite irregular.

Workmen employed in adjusting a hoist passing through the hole in the water-bottom by which to raise disks, when necessary, off the floor, to turn them or to carry them out. This is a slight modification of the

plan already shown for doing this by means of a lever raising a vertical rod, the upper end of which passes through the hole in the water-bottom, and the lower end rests as a pivot on the short end of the lever.

BY FIRST LIEUT. JAMES ROCKWELL, JR.

May 22.—Mr. Hitchcock has been in Pittsburgh for the greater portion of the week, and is satisfied, from consultation with practical men engaged in the iron business in that city, and from his own experiments, that the imperfections in the experimental welds which he has already made are due to the presence of fine particles of coal which are carried over the bridge-wall of the furnace by the too powerful blast, and settle on the welding surfaces, preventing perfect welds. It is now proposed to try the experiment of using a less powerful blast and more coal on the grate to obtain the requisite degree of heat. In this manner it is believed the difficulty alluded to can be overcome and good welds can be obtained.

Mr. Hitchcock expects that his heater will return to him next week, when he will immediately resume experimental work in the presence of Messrs. McDonald and Williams, eminent experts in iron, from Pittsburgh, who made the iron for the disks or rings.

The experimental work done has consisted of work on the apparatus for handling the rings in the heating-furnace, cutting up the forgings for rewelding, and making minor alterations in the furnaces.

May 29.—Mr. Hitchcock has discovered, from consultations with chemists and workers in metals, an additional, and, probably, the principal, cause of failure in the welds he has attempted to make; in the welding-furnace, the two disks or rings to be welded were centered with reference to each other by a +-shaped piece of cast iron, inserted in the holes of the rings. It was Mr. Hitchcock's intention to remove this piece before the heat should crumble or melt it, but this was neglected until too late, and the cast iron melting partially covered the surfaces to be welded, as was ascertained in cutting up the rings for rewelding. Mr. Hitchcock now proposes to obviate this difficulty by substituting for the piece of cast iron two elliptical rings of wrought iron of nearly the same size, riveted together at both ends of the longer axes. These are thrust into the center of the lower ring and being larger than the center of either disk, support the upper disk when lowered upon them, besides affording a means of centering the two disks with reference to each other. They will receive the same degree of heat as the rings to be welded, and can be removed when near a welding heat by flattening them with a few taps of the tongs and drawing them out.

The heating-furnace has been shortened during the past two weeks, the throat being contracted by bricking up to about three-fourths of its former size, and the flue next the throat being also reduced in size. It is intended to use but one of the heating-furnaces, and it is thought that the reduction in size will reduce the consumption of coal one-third or more.

Mr. Hitchcock is also packing his welding-furnace with coke or charcoal, to prevent the rush of air up through the furnace when the cover is removed, and its oxidizing effect upon the disks. He expects the manufacturers of his iron here next week, and will probably make two and possibly three welds next week.

June 5.—The work on Monday and Tuesday was confined to preparations for the welding intended to take place later in the week. The welding-furnace received a packing of charcoal to prevent the rush of

air up through the furnace when the top, or cover, should be swung off. Mr. Williams, an expert in the manufacture and welding of iron, arrived from Pittsburgh on Wednesday afternoon, and the fires in the furnaces were started, and kept up all night. The experimental welding was removed on Thursday, the pieces welded being the three which Mr. Hitchcock had failed to weld satisfactorily in his previous experiments, and which had been cut apart for rewelding. The temperature, time of heating, and hammering were regulated according to Mr. Williams's directions. A higher temperature and longer duration of heat and hammering than heretofore were employed, and to thoroughly cleanse the heated rings, a jet of steam was thrown upon them about half an hour before they were hammered.

The wrought-iron centering rings described in my report of last week worked well, and were easily removed when no longer required. The rings were also more frequently revolved in the welding-furnace than heretofore, to render the action of the flame as even as possible. The rings were considerably bulged out by the increased hammering, and in the latter of the two welds made the small wrought-iron blocks placed between the two rings to separate them and admit of the heating of the under surface of the upper ring, were partially squeezed out between the rings. The metal upon the outer surfaces of the rings had been somewhat melted, and a small quantity had poured down the sides. Every portion of the machinery worked satisfactorily. The rings were removed as soon as sufficiently cooled, and their appearance on Friday morning was very satisfactory, though the outer surfaces were somewhat bulged and irregular. Although they have not been cut up and examined, the welding was considered such a success that Mr. Hitchcock at once commenced work upon the gun proper.

The first large ring for the breech was placed in the welding-furnace, and the second in the heating-furnace, and everything was working satisfactorily when Mr. Hithcock dropped the hammer upon the first ring to round and smooth off its upper surface, and found himself unable to raise it again. A small quantity of steam escaped with considerable noise, and upon examination the flange of the cylinder-head was found to be badly cracked. I believe the cause of this to be the fact that the hammer had been allowed sufficient drop to strike the upper of two rings in the welding-furnace, but Mr. Hitchcock attempted to hammer a single ring without raising it toward the hammer, and although the hammer lightly touched this ring, it fell with nearly its full effect upon the blocks on the upper part of the cylinder-head, which transmitted the blow to the flange under them.

Mr. Hitchcock went to Pittsburgh yesterday noon, and the cylinder-head was this morning shipped to the same place, where he will have a new head cast and drilled. He expects to be able to resume work in ten days or two weeks.

June 12.—The operations have been confined to clearing out and cleaning the furnaces, and to outside and inside turning of the pieces whose welding I described in my last week's report. The outside turning is completed and the welds are exposed, but only distinguishable by an almost imperceptible streak of darker color than the outer surface of the rings. As far as can be judged at present, the welds are perfect. No flaw or seam was found in the outside turning of the mass. As the piece was somewhat irregular in shape, and bulged out from the increased hammering and temperature, the metal turned off varied in thickness from 1½ to 3½ inches. The inside turning is not completed, and will probably require until Tuesday afternoon next to finish it. When the punch

was driven into the holes in the rings to enlarge them and counteract their contraction from the welding, it forced in a considerable amount of scoriæ, and from their presence the inside turning has been difficult and attended with considerable wear to the knives used in the lathe.

The new cylinder-head arrived this morning, but will require the drilling of the flange before it is set up. Mr. Hitchcock is expected to arrive this evening, and active operations upon the gun will probably be resumed early next week.

June 19.—The work until to-day has been confined to turning the pieces welded last week so as to expose the welds, to remove the coke-packing of the welding-furnace and replacing it by pounded asbestos, and to drilling and putting up the cylinder-head of the steam-hammer. The rings whose welding I described in my last report seem perfectly welded, and even a practiced eye can scarcely detect the joints.

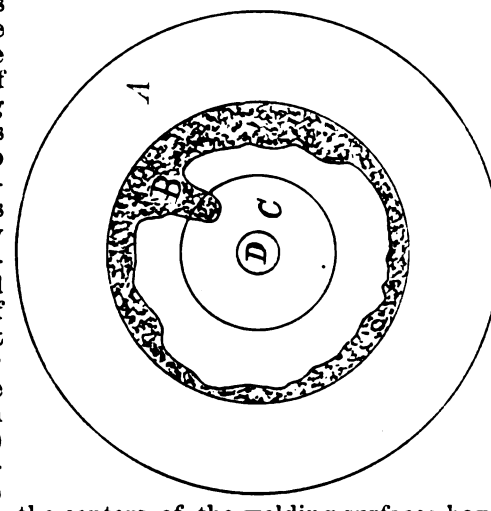
This morning the chamber-piece or ring, and the one adjacent to it on the side toward the breech, were heated, with the intention of welding them, but, from a want of care in centering the two rings in the welding-furnace, the wrought-iron centering-rings were allowed to tip, and so much time was spent in arranging them that the hook at the end of the chain sustaining the transfer-tongs was heated and straightened, allowing the upper ring to drop a short distance. Considerable time was employed in adjusting the upper ring, and as it partially cooled in the mean time, the hammering had not commenced when I left the plant in order to prepare this report, the opinion of Mr. Hitchcock and his heater being that a welding-heat would not be obtained within the next hour or hour and a half. The welding was experimental, Mr. Hitchcock not intending to resume operations upon the gun itself for the present.

June 26.—The inside and outside turning of the pieces welded on the 5th instant were completed the first of the week, and no flaw or imperfection is visible, the welding being apparently perfect. The pieces are now ready for cutting up, should it be considered advisable. The two large rings which were welded last Saturday are now being turned down on the outside. The metal is considerably cracked on the exterior, probably from overheating. Before the turning was commenced, the joint between the rings could be plainly seen all the way around. Since then about three-eighths of an inch in thickness of metal has been turned off, and the weld is now scarcely distinguishable.

It is proposed to turn off about an inch more from the outer surface, and this will be finished by the middle of next week, when the boring and inside turning can be commenced. The two pieces are the chamber-ring and the breech-ring, with the turning-knob or cascable. They are solid pieces, and together will weigh about 7,000 pounds. The weld is an excellent one, so far as can be judged at present.

July 17.—The two solid rings composing the breech of the Hitchcock gun, and whose welding took place on the 19th ultimo, have been partially bored out to ascertain whether the weld was perfect from surface to center. When the boring had reached a diameter of 6 inches, a gap or crack large enough to admit the finger was found about where the weld should have been. The mass was then cut into from the outside a uniform depth of about 6 inches, opposite where the interior crack had been discovered when the gap was reached. By means of small iron wedges, the two rings were readily split apart, and the following diagram roughly illustrates the appearance of the surface where the welding should have taken place. A represents the part cut into, 6 inches or a little less in thickness; B shows where partial union occurred, the metal being burned, and having lost very much of its tenacity; C is the solid center, in which was bored the hole D.

Except for the presence of shallow cracks on the surface, caused by overheating, the weld throughout A was perfect until the part B was nearly reached, when it was found that a penknife-blade could be pushed up under the surface in prolongations of the gap referred to, it being probable that in these places the cutter had cut a little to one side of the welding-surface; throughout C there was no weld, the iron being only slightly discolored, and it appears as though the rings had never met in this portion of their surfaces. The most reasonable explanation for this is that the base of the hammer has been so much cupped (or made concave) that only the part near the circumference has struck the upper ring, and consequently the centers of the welding-surfaces have never been hammered together. This would probably not occur in small rings with holes in the centers, but those in question are the largest rings used in the gun, and are solid.



The appearance of this weld is most unsatisfactory, and the defect is in that portion of the rings where it could never be found until the gun had been subjected to the firing test.

REPORT OF CAPT. GEORGE D. RAMSAY, JR., ORDNANCE CORPS.

NATIONAL ARMORY,
Springfield, Mass., July 31, 1875.

SIR: In compliance with your verbal instructions of June 30, I have the honor to submit the following report on the fabrication and procurement of the plant for the Hitchcock gun, and on the progress which has been made in the manufacture of the gun itself.

REPORT.

On February 7, 1873, the Chief of Ordnance ordered the commanding officer of the National Armory to prepare to manufacture the Hitchcock gun; this order was received at the armory on February 10, 1873.

The inventor, Mr. Alonzo Hitchcock, reported to the commanding officer on February 12, and after full consultation with him, the commanding officer made a careful estimate of funds necessary for the manufacture of the gun and on February 13 made a requisition for $50,000.

Every facility was offered Mr. Hitchcock to enable him to carry out his plans in procuring the necessary materials and in fabricating the gun-machinery and the gun itself. He was authorized to visit such establishments as he might desire to inspect for the purpose of obtaining information in regard to the manufacture of iron for the gun, and of having parts of the machinery manufactured. He had a general supervision of all the details of the work done at this armory in con-

nection with the Hitchcock gun, and all work done at private establishments was subject to his directions and inspection. During the year 1874 Mr. Hitchcock was allowed to spend much of the time in experimenting on the manufacture of gun-iron at Pittsburgh and Lewistown, Pa., so that his plans might be carried out exactly. Mr. Hitchcock was at the beginning requested to prepare detailed drawings of his proposed gun-machinery, and the services of Mr. C. A. Emery, the National Armory draughtsman, were placed at his disposal for that purpose. Detailed drawings of the principal parts of the machinery were prepared during the months of February, March, and April, 1873. Apparently from vagueness in his plans, Mr. Hitchcock did not have any drawings made of a part of the plant until the work of putting it together had begun, and when the mechanics were embarrassed in their operations by the need of working-drawings. A special draughtsman was then employed from October, 1873, to March, 1874, to make drawings which should have been furnished before the work began.

A natural bed of rock was considered necessary by Mr. Hitchcock for a foundation for the gun-machinery; and after a careful examination of the ground, he recommended that it should be placed in the "drop room" of the water-shops. On the 14th of February, 1873, the work of removing the drops and other machinery from this room commenced, and in two weeks was finished. Ground was then broken for the pit in which the hydraulic anvil was to be placed. After passing through five feet of earth, a ledge of new red sandstone-rock was struck. For a few feet the rock was soft, but the rest of the pit was sunk through a solid bed of rock. This work proceeded slowly, as much care had to be exercised in blasting so as to avoid injuring the walls of the building. Much difficulty was experienced from water flowing in from numerous springs. To free the pit from water, two small upright pumps were kept running all the time until May 15, when a rotary pump was purchased and substituted for the others with excellent results. The excavation was completed on May 30, 1873, the pit being 40 feet deep and 14 feet in diameter at the bottom.

Under the directions of an experienced workman, kindly furnished by General Gillmore of the Engineers, experiments were made with various kinds of concrete for the foundation. On July 2 the first concrete was lowered into the pit. It consisted of one part of cement, four of sand, four of gravel, and four of broken stone. The bottom of the pit was filled with this concrete to the depth of four feet. In a few hours it was very hard and solid. The wall was raised for the first two feet with concrete composed of one part cement, three of sand, and two of broken stone. The next four feet of the wall was built of concrete composed of one part of cement, three of sand, three of broken stone, and three of gravel. The remainder of the wall was built of concrete composed of one part of cement, four of sand, three of broken stone, and three of gravel. The wall was finished July 18, 1873. Points of support for the columns upon which the steam-hammer was to rest were cut into the solid rock.

In a few weeks it was found that the concrete wall surrounding the pit was not water-tight, and on August 20, 1873, an iron tank, 16 feet high and 10 feet in diameter, was ordered from De Laney & Co., of Buffalo, N. Y., to serve as a lining for the pit. As this tank was too large for easy shipment, it was made in sections at Buffalo, and after its receipt here on October 1 it was finished, and on October 30 was placed in the pit. From the top of the tank the concrete wall was then raised five feet.

In the mean time measures had been taken to procure materials for the plant. Mr. Hitchcock visited various iron-works to seek information on the subject. The hydraulic cylinder and all other necessary cast-iron work for the plant was ordered from Macintosh, Hemphill & Co., of Pittsburgh, Pa., on February 27, 1873, but, on account of other work on hand, that firm did not begin to make the castings until the early part of April. The cylinder and piston for the hydraulic anvil were not received until October, 1873. The wrought-iron shaft for the steam-hammer was ordered from the De Laney Forge & Iron Company, Buffalo, N. Y., on February 28, 1873. After a long delay, this shaft was forged, but while being finished it was found to be defective, and on November 6, 1873, a new one was ordered. The new shaft was received on February 9, 1874.

In July, 1873, fifteen large steel rings were ordered from William Butcher & Co., of Philadelphia, Pa., for the purpose of making an exterior jacket to give additional strength to the hydraulic cylinder. They were received on August 5. All the heavy castings for the hydraulic anvil were received on October 25, and the cylinder for the steam-hammer was received November 5, 1873. During the month of November the rings were bored out and finished to the proper size. A temporary shed was built, in which the hydraulic cylinder was placed upon the base upon which it was to rest; the rings were then heated and shrunk on the cylinder while in this position. The cylinder was then removed from the base to have the hole for the pump bored in it. While these preparations were going on, a portion of the roof of the "drop-room" was removed and an addition of boards covered with sheet-iron was made to the building, sufficiently high to admit of the erection of the steam-hammer.

The heavy oak timbers for the foundation and the large iron beams for the columns for the support of the steam-hammer, were received from Watervliet Arsenal during the summer of 1873. In August, the plate-iron for these columns, and for the girder which surmounts them, was ordered from Graff, Bennett & Company, of Pittsburgh, Pa. A small portion of it was received in October, and the rest in November. The angle-iron for the girder was received September 24, 1873, from the Union Iron Company, Buffalo, N. Y., as was also the iron for the guide-beams of the hydraulic anvil, and the supports for the welding-furnace.

The work of building the columns and the girder began in November, 1873. After the work began some changes were made in the manner of bracing the girder, which rendered it necessary to procure additional iron. This iron did not arrive until January 30, 1874, and, in the mean time, on January 17, one of the girder-plates was found to be defective, and a new one was ordered, but was not received until February 26. The girder was not finished until early in March. There were numerous delays during the building of the girder, caused by the changes which were made in it and in waiting for the iron.

On November 20, 1873, Mr. Hitchcock decided that the holes which had been cut in the rock to receive the columns should be lowered four feet. As blasting could not be resorted to without injury to the concrete wall, the rock had to be cut away, which was a very slow operation. Stone foundations for the columns were then built.

On June 25, 1873, a lot of heavy gun-carriage timbers was received from Watervliet Arsenal. During January, 1874, they were prepared and lowered into position at the bottom of the pit, to form a part of the foundation for the hydraulic anvil. Two tiers of timbers were used. Upon these timbers was placed a heavy round recessed plate of cast

iron. A massive block, composed of a number of oak blocks on end, bound together by wrought-iron tires, was placed on top of this plate and fitted into the recess. On February 6, 1874, the heavy cast-iron base of the hydraulic cylinder was lowered down on top of this block, and firmly bound to the foundation by means of iron bolts. On February 9, the shaft for the steam-hammer was received. The hydraulic cylinder, having been strengthened and fitted up, was lowered into its place on February 11, and fastened to the base by means of heavy iron bolts, which passed through the head of the cylinder and locked into holes cut in the base for that purpose. On February 28, the work of setting the guide-beams for the plunger of the hydraulic-anvil began.

On March 10, the columns or beams for the support of the steam-hammer were raised and set in position, and the girder having been attached to the steam-hammer cylinder, was raised on March 19, and placed in position on top of the supporting columns. The packing ring for the hydraulic cylinder was received March 18, and its pump on April 4.

On account of delay in receiving materials, and also on account of the absence of Mr. Hitchcock, at Lewistown and Pittsburgh, Pa., where he was urging forward work on the furnace-castings and experimenting with gun-iron, the work progressed very slowly for several weeks.

During the month of April, the anvil-plunger was lowered into the cylinder, and the hydraulic anvil was fitted up.

On May 13, the iron plates for the furnace chimneys were received from Graff, Bennett & Co., Pittsburgh, Pa., already punched. The chimneys were commenced on May 26, and were completed before the end of June.

On account of the non-arrival of the castings for the furnaces and the continued absence of Mr. Hitchcock on business connected with his experiments on gun-iron and the purchase of a suitable gun-lathe, but little work was done for some time. Only two men were at work by July 13, and a week later work was entirely suspended until Mr. Hitchcock's return on July 25.

Steam was let on for the first time on August 4, 1874, to test the working of the steam-hammer. The hammer would not work at all, as it bound against the steam-cylinder, and it was found necessary to file the shaft considerably to make it work freely. A test of the hydraulic anvil showed the necessity of filing the piston also. The hammer-shaft was filed and steam was let on again on August 13, with but little better success. After more filing, another trial was made on September 1, but the hammer could only be raised two feet. During this time the piston of the hydraulic anvil was also filed, till it worked freely. The packing-box of the steam-cylinder was then bored out and "bushed" with Babbitt metal. After various trials, the hammer worked satisfactorily on October 28. This trouble would have been obviated had Mr. Hitchcock made a careful inspection of these machines when he visited the iron-works for that purpose. During this delay the pump of the hydraulic anvil was moved to a more convenient position and a portion of the roof of the building was raised to make room for one of the furnaces. This change was made necessary by a mistake which had been made in not sinking the anvil-pit sufficiently deep.

The gun-lathe, which had been purchased from Macintosh, Hemphill & Co., of Pittsburgh, Pa., was received early in November, and was placed in position on the foundation which had already been prepared for it. On November 13, the first lot of iron for the 9-inch gun was received from Graff, Bennett & Co., of Pittsburgh, Pa., with whom a contract had been made on June 22, 1874.

Nearly all of the castings for the furnaces having arrived, the work of building the furnaces began on December 7, and they were completed on January 23, 1875, with the exception of setting the dampers, the castings for which had not been received. This work was finished on February 18. During the building of the furnaces the cranes for handling the gun-iron were built. During the month of March the floors were laid and all the arrangements were completed to begin the manufacture of the gun.

On April 5, 1875, George Ormsby, an experienced heater, from Lewistown, Pa., arrived, and the furnaces were heated up to dry the brickwork thoroughly. They were found to draw well and the blast was amply strong. Two days afterward preparations were made to heat one of the gun-disks, but the "water-bottom" of the heating-furnace burst and put a stop to the work. A false bottom of sand for experimental purposes was made, in the hope of dispensing with the water-bottom.

On April 9, a large wrought-iron tool was forged for the purpose of turning the blocks of the anvil so that the iron disk, resting on it in the furnace, might be turned and exposed uniformly to the heat.

The next day two disks were heated ready for welding, but owing to the delay in bringing them together, caused by the novelty of the work to most of the men, the disks became too cold to be welded.

Two disks were welded in the morning of April 13, but in the afternoon the water-bottom failed and put a stop to the work by deluging the furnace with water and generating clouds of steam. Fortunately no one was injured by this accident. This was the old cast-iron water-bottom which had broken previously and had been repaired by shrinking a wrought-iron band around it. It was subsequently ascertained that the weld which was made in the morning was imperfect. This day's work, however, was a good drill for the helpers, as they received much instruction in their duties and became accustomed to the intense heat in handling the heated disks.

As the heating-furnace could not be used, on account of the broken "water-bottom," the attempt was made, on April 14, to heat two disks in the welding-furnace. The disk for the bottom of the breech of the gun was first heated in this furnace and the thin disk, which is intended to finish the breech and to contain the ratchet-holes for elevating, was then placed, while cold, on top of the hot disk and the furnace was closed. The two disks were then exposed for one hour to what was considered a proper degree of heat. The top of the furnace was then removed and the hammer was dropped about twenty times upon the two disks. In the mean time a block of wrought iron, intended to be used as a bearing to fasten the breech end of the gun in the lathe, was brought to a welding heat in another part of the same furnace; it was then placed upon the top of the thin disk and welded by repeated blows of the hammer. Upon removing the mass from the furnace, the block was found to be welded to the thin disk, but there was no weld between the thin disk and the breech disk. In other words, a good weld was formed between surfaces brought together after they had both been brought to a welding heat, but no weld occurred where a cold surface was brought in contact with a hot one and then both of them heated to a welding heat together.

After this experiment, which showed the necessity of using both of the furnaces, the heater returned to his home to await the necessary repairs to the furnace. A new water-bottom, stronger than the old one, and made of wrought iron, was made and placed in the heating-furnace. The head of the steam hammer was at the same time removed from the shaft and placed in the gun-lathe. Its face was turned

slightly concave, so as to give a convex surface to the upper face of the disks forged under it, and thus to promote the radial expression of cinder in welding.

This work having been completed, and the heater having returned, the furnaces were started again on April 29. The disk and block which had been welded together on April 14 were placed in the heating-furnace with the disk uppermost, and heated for four hours. When this mass was in a nearly pasty condition a small block of wrought iron was heated and tamped by means of an iron bar into the center of the disk to cover some slight flaws on its surface and also to dowell this disk to the next one which would be welded to it. During this time the large breech-disk was heating in the welding-furnace; the block and disk were then removed from the heating-furnace to the welding-furnace and placed (block uppermost) upon the large disk, but kept from actual contact with it by means of four small blocks of wrought iron which had been laid on the surface of the large disk; the space between the welding surfaces being about two inches. The furnace was closed, and the disks were exposed to the heat for twenty minutes; they were then turned around on the anvil by means of the movable anvil-blocks, and heated for twenty-five minutes longer. The hammer was then dropped repeatedly. The weld appeared to be a good one. The side of the disks longest exposed to the blast of heat was slightly fused and some slight cracks were found on the outer edges. There was a considerable escape of steam and consequently a constant dripping of water from the steam hammer, which was attributed to the infrequent use of the hammer. Five welds were made on April 30 and everything worked well till the last heat, when the water-bottom leaked. The pieces welded this day were afterward cut up, and the welds were found imperfect.

During the month of May Mr. Hitchcock visited Pittsburgh to procure an additional supply of experimental iron; the water-bottom was repaired and the hammer was again placed in the lathe to have its face turned. The heating-furnace was shortened, the throat being contracted by bricking it up to about three-fourths of its former size, the flue next to the throat being also reduced in size. This change made a considerable reduction in the large consumption of coal.

The fires were again started in the furnaces on the afternoon of June 2 and kept up all night, and the next day two heats were taken successfully under the instructions of an expert, Mr. Williams, of the firm of Graff, Bennett & Co., of Pittsburgh, Pa.* During the heating on the 4th of June the steam hammer was dropped to give proper shape to one of the disks which was heating, and as the anvil was not properly adjusted for that purpose, the hammer fell with such force as to burst the cylinder-head.

A new cylinder-head was received from Pittsburgh on June 12, and when fitted up was substituted for the broken one.

On June 19 another attempt was made to weld together two large disks to form the breech of the gun. So much time was spent in centering these disks in the welding-furnace that the hook at the end of the chain sustaining the transfer-tongs became heated and straightened out, allowing the upper disk to fall. In consequence of this mishap the disk became too much chilled before it could be placed in the proper position for welding; it was therefore reheated, and at a second attempt

*The pieces which were welded under the directions of Mr. Williams were subsequently turned, bored, and cut into slabs across the welds, and the welds were found to be perfect.—G. D. R.

the weld was made, everything working well. Subsequent boring and cutting showed that the weld was very imperfect.

The work accomplished since April 1, 1875, of which this report is but a sketch, is more fully described in the very interesting weekly reports of Lieutenant Metcalfe and Lieutenant Rockwell.

On June 24 Mr. Hitchcock addressed a letter to the commanding officer of the National Armory, declining to proceed further with the manufacture of his gun, on the ground that the welding could not be done with the present style of furnaces. As the appropriation was so nearly exhausted, all work upon the gun was then stopped.

The COMMANDING OFFICER, NATIONAL ARMORY.

LETTER OF MR. ALONZO HITCHCOCK.

JUNE 24, 1875.

DEAR SIR: After two years and nine months' continuous labor I have to report a general outline of the progress and results of my experiments in forging wrought-iron guns, which have been done under an order from the Chief of Ordnance of the Army, dated September 18, 1872.

Like all new mechanical devices, the first experiments must necessarily be slow, tedious, and subject to many perplexities and delays, the present one not being an exception to the rule. But taking into consideration the novelty and extent of the mechanical devices, the radical change that is proposed to bring about in the manufacture of heavy ordnance, there may be some excuse for such delays; but whether so or not, it is not proposed to discuss this point here, but simply to say this: the machinery is all in place, and it all works satisfactorily in principle and practice, and fully answers my expectations; which is saying a good deal.

With all these flattering prospects and results, I feel it my duty to arrest the work even now, when we are ready to go on and weld up the first gun, (9-inch.) Below will be found the main reasons for my assuming such an unpleasant duty:

First. The Government is furnishing me the money to spend in developing my own devices, and will very justly hold me responsible for the success or failure of the same, especially the failure, if there is one.

Second. Notwithstanding the machinery all works satisfactorily, I find that by practical operation there is great danger of uncertainty about the working of the old reverberatory furnaces which we have now in the works. This was, however, well understood by the ordnance board; and all practical furnace-men knew that there are better furnaces in use, as, for instance, the gas or Siemans regenerating furnace, but simply for prudential motives it was deemed sufficient to test my mechanical mode of welding up guns as I proposed, leaving the furnaces for future consideration if the machinery would do the work as was promised.

Having taken the precaution to commence by welding up some small samples before commencing on the gun, I was led to believe that there was not only an uncertainty, but it is almost if not an absolute certainty, scientifically, practically, and mechanically, to make all the welds perfect, and probably a considerable proportion of imperfect welds might be made, while one bad weld would be disastrous, if not absolutely fatal to the whole project.

Not being an expert in the furnace business, there was no alternative but to go to the practical and scientific men for information, and see the practical operation of all the latest improvements in furnaces, which I accordingly did; and the result is we are trying to make impossible things possible, and going squarely in the face of all known facts in science and practical knowledge that have been developed within the last ten or twelve years.

Third. However much I may regret this delay and additional expense, knowing what I know now, it would be no less than criminal stupidity on my own part and a fraud upon the Government to persist in going on to accomplish so important a project as this promises to be with such appliances or devices as are known to be imperfect, when it is well known that such imperfections can be avoided.

Not to mention personal interest, the Government has spent too much money on this plant to solve the great question, "how to make the best gun," to afford to make a failure if it can be prevented.

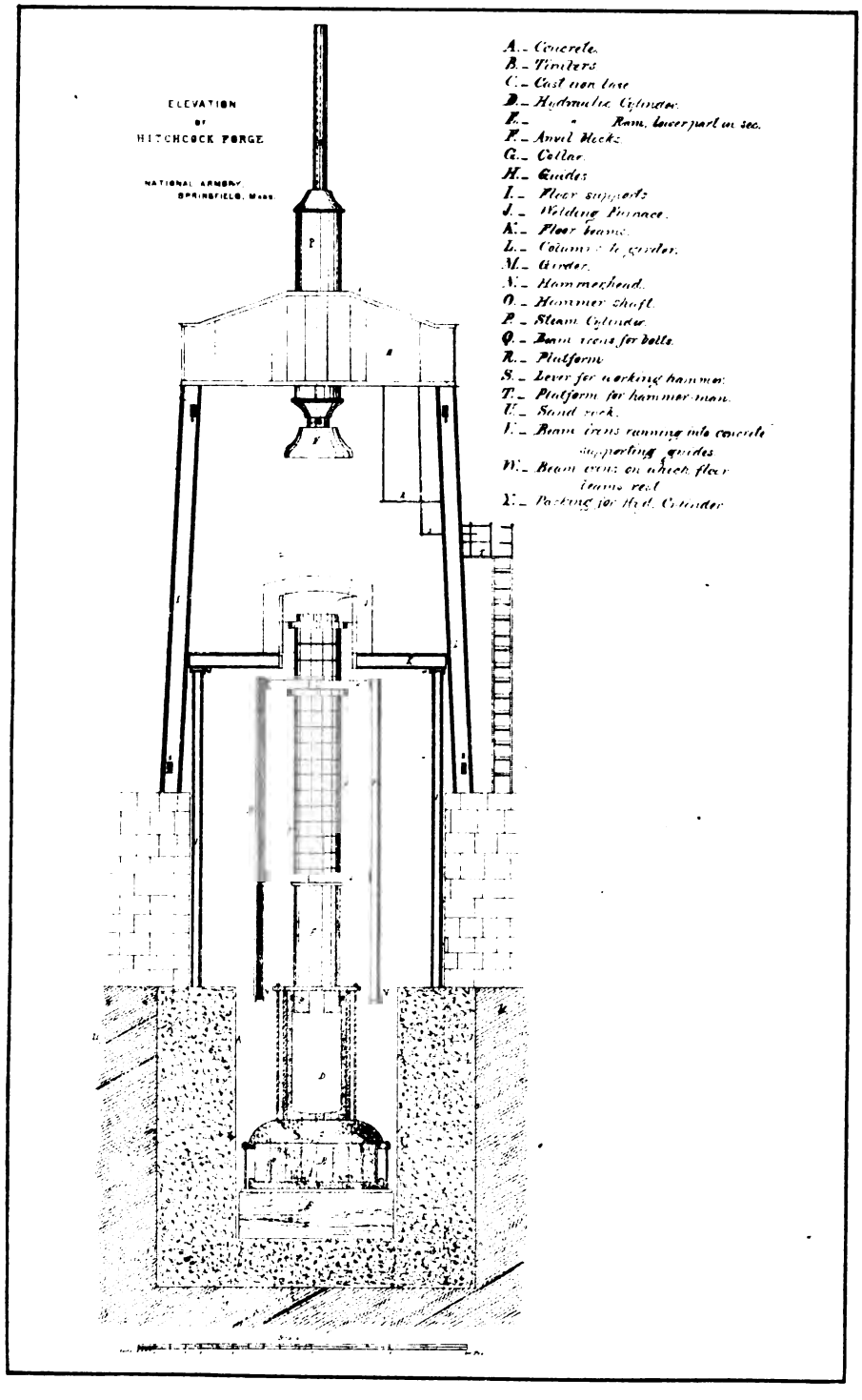
Very respectfully,

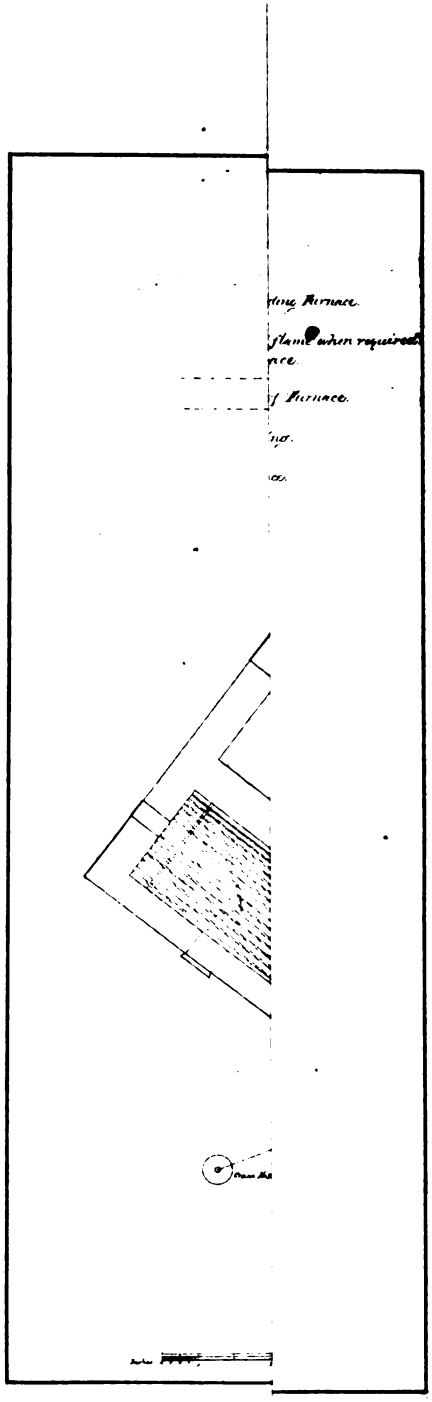
ALONZO HITCHCOCK.

Col. J. G. BENTON,
Commandant National Armory, Springfield, Mass.

NOTE.—To prevent misunderstanding, it may be proper to state that in the sentence in the foregoing communication in which Mr. Hitchcock speaks of the "old reverberatory furnaces which we have now in the works," he probably intends to describe the form and nature of these furnaces. All parts of his gun machinery, including the furnaces, were designed by Mr. Hitchcock after consultation with experienced furnacemen in Pittsburgh and elsewhere, and were constructed under his immediate supervision, and without limitation in the selection of the nature of the furnace.

J. G. BENTON,
Lieutenant-Colonel of Ordnance, Commanding.


ELEVATION
OF
HITCHCOCK FORGE.
NATIONAL ARMORY,
SPRINGFIELD, Mass.
A.- Concrete.
B.- Timbers
C.- Cast iron base
D.- Hydraulic Cylinder.
E.- " Ram, lower part in sec.
F.- Anvil Blocks
G.- Cellar
H.- Guides
I.- Floor supports
J.- Welding Furnace.
K.- Floor beams.
L.- Column & girder.
M.- Girder.
N.- Hammerhead.
O.- Hammer shaft.
P.- Steam Cylinder.
Q.- Beam irons for bolts.
R.- Platform
S.- Lever for working hammer.
T.- Platform for hammer-man.
U.- Sand sack.
V.- Beam irons running into concrete supporting guides
W.- Beam irons on which floor beams rest
X.- Packing for Hyd. Cylinder


Furnace.
flame when required
Furnace.

APPENDIX P.

Recommendations of a board of ordnance officers, convened under the provisions of the act of Congress approved March 3, 1875, in regard to the sale of arsenals.

UNITED STATES ORDNANCE AGENCY,
New York City, June 1, 1875.

Recommendations of a board of ordnance officers, convened in pursuance of the following order, to wit:

[Special Orders, No. 97.]

WAR DEPARTMENT, ADJUTANT GENERAL'S OFFICE,
Washington, May 22, 1875.

[EXTRACT.]

* * * * * * *

3. In pursuance of the act entitled "An act making appropriations for sundry civil expenses of the Government for the fiscal year ending June 30, 1876, and for other purposes," approved March 3, 1875, published in General Orders, No. 24, March 16, 1875, from this Office, a board of ordnance officers, to consist of Lieut. Col. Silas Crispin, Maj. T. J. Treadwell, Maj. T. G. Baylor, is appointed to meet in New York City, on the 1st day of June, 1875, or as soon thereafter as practicable, to visit and examine into the condition of the United States arsenals east of the Mississippi River, and to report how many of the same can be sold without interfering with the necessities of the military service, together with an estimate of the amount that can probably be realized from the sale of the same.

The visits will be made at such times as can be done without interfering with other duties.

The board will make their report to the Chief of Ordnance on or before October 1 next.

The junior member of the board will act as recorder.

The following is the paragraph of the act of Congress above referred to:

"And the Secretary of War is hereby directed to cause an examination to be made into the condition of the United States arsenals east of the Mississippi River, and report to the next Congress how many of the same can be sold without interfering with the necessities of the military service, together with an estimate of the amount that can probably be realized from the sale of each of the same whenever such sale shall be directed by Congress."

* * * * * * *

By order of the Secretary of War:

E. D. TOWNSEND,
Adjutant General.

Official:
L. H. PELOUZE,
Assistant Adjutant General.

The board finds, from an examination of the records before it, that an exhaustive and comprehensive study of our present arsenal system, its facilities and its requirements, was made by the board on arsenals, con-

vened under order of the Department, dated November 12, 1873, for the purpose of reporting "on the best method of concentrating the manufacturing operations of this Department east of the Mississippi River, either by the establishment of a grand arsenal on the Atlantic seaboard, or the enlargement of, and concentration of work in, one or more of our arsenals, discontinuing the remainder of the arsenals, or retaining one or more as mere places of deposit." That report embodies the following plan:

"PLAN 1.

"The Ordnance Department, for nearly the last thirty years, in the performance of the various duties intrusted to it by law, under the Secretary of War, in the manufacture and procurement of all ordnance and ordnance stores for armies called into the field at different times during this period, also in the providing of warlike stores for the prospective wants of future armies, the armaments and material for sea-coast defenses, the material for arming and equipping militia, and the performance of the important experimental duties intrusted to its care, has experienced during this period more or less serious embarrassment, not only from the inadequacy of existing facilities at the present arsenals of construction, but from their locations and limited resources, necessitating the conduction of the manufacturing operations at different points, widely separated, and being more or less objectionable on account of transportation, procurement of labor and material, and at the loss of the evident economy of a judicious concentration of ordnance manufactures.

"Our present arsenals of construction, located between the Mississippi River and Atlantic Ocean, are widely scattered from Maine to Georgia. This policy of location was necessary at the time of their establishment, when but few, if any, railroad means of transit existed in our country, and when it was important, from this cause, that equipment of troops should be made at or near the localities where raised.

"But at the present day, when our elaborate and perfected railroad and telegraph systems of communication have rendered the question of distance one of but secondary importance, we can now take advantage of these improvements, and subserve the true interests of economy, perfect our products, and attain the other manifest advantages of a policy of centralization by a concentration at one grand arsenal of the most important manufacturing operations of the Department.

"The great importance of carrying out this policy at a 'grand arsenal on the Atlantic seaboard' has been fully recognized and urged in the report of the Chief of Ordnance, of December 3, 1862, and repeatedly pressed upon the notice of the War Department, and the action of Congress earnestly recommended in the subsequent annual reports of this Office from 1869 to 1873.

"The first consideration in the location of an arsenal of construction to effect these ends is, evidently, that it should occupy a comparatively central geographical position with respect to the Atlantic seaboard, and have at command the facilities of one of our great commercial centers.

"The pre-eminence of the city of New York, in its gigantic means for transit and for prompt distribution of all warlike stores to all points of the United States, its unsurpassed resources in labor and material, and its advantages in a geographical point of view over any city on our coast as a distributing-point, renders the location of an arsenal-site in its vicinity, if practicable, of the greatest importance; and accordingly the board has directed its examination particularly to this section of the country.

"A consideration and examination of the surroundings of New York point conclusively to the immediate north of Newark, N. J., as the section of country possessing the best advantages, and as being most eligible and desirable for locating the proposed arsenal.

"The land here bordering on the Passaic River rises from the level of the river to a height of over 100 feet, and then gradually slopes eastward to the meadow-lands bordering on the Hackensack.

"The character of the ground gives it natural features of defense, and this, added to its location (see Map 1) with respect to important works of defense of New York Harbor, and its freedom from the possibility of naval attack, are considerations of the highest importance.

"The diverging main lines of railroad from Jersey City and Hoboken, at present eleven in number, bring this site in close and rapid communication with New York and the country at large, and the water-facilities of the Passaic and Hackensack are available for transportation of supplies to and from the harbor of the commercial metropolis of our country.

"A special site on this ground has been selected and surveyed (see report of Mr. H. N. Babcock, marked L") and is represented in detail on map marked 2.

"Its location with respect to New York City; Newark, and the surrounding country, also with respect to railroad and water means of transit with New York, is shown by the accompanying map, marked 3.

"It will be seen (Map 3) that this site is distant about * * from New York, and about three miles from the suburbs of Newark. It has a frontage on the Passaic of * * * * *, and extending eastward, as it does, from the Passaic River to the Hackensack meadows, it thus has access to both rivers.

"A short line of railroad * * * will connect the site with the railroad system of the country, and at a slight cost of construction, owing to the level character of the adjacent lands.

* * * * * * *

"A suitable proof-ground for ordnance adjoining the arsenal-site is shown on Map 3, and marked (P. G.) * * * It would constitute a valuable adjunct to the arsenal, and it is recommended that it be secured if the site for the latter be approved and purchased.

"The above-recommended purchases do not provide for storage-depots on the waters of New York Harbor, to be especially utilized in times of war. Our recent past experience in the rebellion has shown that such facilities can be readily extemporized when needed from buildings and wharfages already existing for ordinary commercial purposes in New York Harbor, and at a less cost than would be incurred in their permanent provision by the Government.

"It would appear, from the above considerations and facts, that a 'grand arsenal' of construction can be located, at a reasonable and moderate cost, on the Atlantic coast, and at the most desirable point for the concentration of ordnance manufactures.

"In view of this fact, there remains to be considered and determined the proper distribution of the duties of the Department, based upon the early establishment of this arsenal, and the proper disposition of such arsenals as its erection will render no longer needed for the services of the United States.

"The arsenals and armories now established east of the Mississippi River are as follows, to wit:

"Kennebec Arsenal, Augusta, Me.

"Watertown Arsenal, Watertown, Mass.

"Springfield Armory, Springfield, Mass.
"Watervliet Arsenal, West Troy, N. Y.
"New York Arsenal, Governor's Island, New York Harbor.
"Pikesville Arsenal, Pikesville, Md.
"Frankford Arsenal, Philadelphia, Pa.
"Washington Arsenal, Washington, D. C.
"Fort Monroe Arsenal, Old Point Comfort, Va.
"Augusta Arsenal, Augusta, Ga.
"Indianapolis Arsenal, Indianapolis, Ind.
"Columbus Arsenal, Columbus, Ohio.
"Allegheny Arsenal, Pittsburgh, Pa.
"Detroit Arsenal, Detroit, Mich.

"The principal manufacturing operations of the Department are now performed at the following arsenals, to wit: Watertown, engaged in the production of sea-coast carriages and projectiles for heavy guns; Springfield Armory, in the manufacture of small-arms; Watervliet, in the manufacture of leather-work; Frankford Arsenal, in small-arm ammunition, and Fort Monroe Arsenal, in sea-coast-carriages and on experimental duties. The remaining arsenals in the above list are either engaged in small repairs or are simply storage-depots for the care and preservation, issue and receipt, of ordnance and ordnance-stores. It is believed that, except small-arms and small-arm ammunition, the more important ordnance and ordnance-stores, more especially those for field and siege artillery, and those to be provided for the use of our sea-coast defenses, such as cannon, heavy sea-coast carriages, projectiles, and ammunition, and other stores and appliances for their service and maneuver, also harness and the more elaborate articles of leather-work, should all be made at the grand arsenal of construction.

"The manufacture of our small-arms and small-arm ammunition for our present armies and militia, and for our reserve supply, is one of the greatest importance, and as the Springfield Armory is a model one of the world in the perfection of its fabrications, and the extent and completeness of its arrangements and facilities for the production of this class of warlike stores, the board regards the retention of this establishment as a foregone conclusion, in its proposed plan for concentration, for the fabrication of its present specialty, and such other work as its facilities may accommodate. Recognizing also the almost imperative necessity, in order to secure perfection in production in the fabrication of small-arms and small-arm ammunition, that they should be produced side by side, the board is of the opinion that arrangements should be made for the transfer of the present manufacturing operations of small-arm cartridges at Frankford Arsenal to the Springfield Armory as early as it can be accomplished with economy and with a due regard to other important public interests. The more simple leather-work fabrications of infantry and cavalry accouterments, and perhaps some other kinds, all demanded in quantity, and requiring little but no special appliances for their manufacture, can, it is thought, be economically and judiciously made at one of our present arsenals. The board recommends the retention of the Frankford Arsenal for this purpose. Its geographical position and its facilities of shops and store-houses and for material and labor of the kind required, its means of transit, and its close and quick connection with the proposed grand arsenal at Newark, N. J., point conclusively to its retention for the purpose suggested, and as part of the proposed plan for concentration.

"It will be seen that the design contemplated by the board is to con-

centrate all the principal manufacturing operations of the Department at the proposed grand arsenal, the Springfield Armory, and at Frankford Arsenal.

"It remains now to designate those arsenals which it is proposed shall be retained to meet the wants of the country as arsenals for storage and repair, and those to be used simply as depots for the care, preservation, receipt, and issue of warlike stores.

"A careful and mature consideration of the question leads the board to recommend the retention of the following arsenals, to wit: Augusta and Fort Monroe as arsenals of storage and repair, and Kennebec, New York, and Indianapolis Arsenals as depots for storage and issue. This will leave to be sold the Watertown, Watervliet, Pikesville, Washington, Allegheny, Columbus, and Detroit Arsenals.

"The reasons for the retention of the above arsenals, as recommended by the board, are as follows, to wit:

"*Augusta Arsenal.*—This is the only arsenal left in the entire South, east of the Mississippi, and the nearest constructing arsenal to it in the proposed plan will be nearly eight hundred miles distant. Its retention and improvement and sufficient enlargement to render it adequate to supply the needs of the Department in the South, in the opinion of the board, is a matter of wisdom, and in fact a necessity. The proposed improvements and enlargement (see memorandum letter of board addressed to Captain Hill, March 7, 1874, official copy of which was sent to that officer March 16, 1874, and the report of that officer dated March 16, 1874,) can be secured at a moderate cost. Its present workshops and buildings are in excellent condition, and are sufficiently large in plan to be utilized almost without cost in the remodeling of the arsenal as one for storage and repair. The location, inland, is one of the best in the South, both geographically and in its rail and water facilities, for the reception and distribution of supplies for the South. These and its other advantages for the purposes required, (see Captain Hill's report,) and its general healthfulness, further confirm the board in its opinion as to the propriety and necessity of retention of the Augusta Arsenal. Its general plan and its location with respect to Augusta City are given in the accompanying map marked 4.

"*Fort Monroe Arsenal, Virginia.*—This arsenal is situated on a Government reservation, and its connection with Fort Monroe renders its sale impossible. It is well provided with shops and machinery, and is admirably situated geographically on the waters of Hampton Roads for fitting out expeditions, as was shown in the late war.

"The arsenal as it now exists, however, is considerably scattered over the Government reservation, and, as a matter of economy and efficiency, it is recommended by the board that all the arsenal property inside the fort, consisting of quarters, barracks, and office, be turned over to the garrison of Fort Monroe. The store-houses and other temporary buildings should be torn down and the materials applied, as far as practicable, to the erection of suitable structures, rendered necessary by this action, outside the fort in the vicinity of its shops. The necessary buildings required to be erected by this plan would cost but little additional to the value of the material obtained by the removal of the store-houses and buildings inside the fort. The buildings inside the fort should not be abandoned or turned over until their places are supplied by suitable structures contemplated to be erected outside the fort.

"*Kennebec Arsenal.*—This arsenal is situated on our northeastern frontier, bordering on Canada, is well located, has the requisite facilities, and is deemed necessary for retention to supply the present and prospective wants of that section of our country.

"*New York Arsenal.*—This arsenal, located on the glacis-slope of Fort Columbus, Governor's Island, is not available for sale. Whilst incapable of and having no manufacturing facilities, yet it has comparatively extensive storage capacity and wharfage, and superior facilities, from its location in New York Harbor, for the distribution of supplies, and will thus form a valuable adjunct for storage in connection with the proposed grand arsenal.

"*Indianapolis Arsenal.*—The construction of a large arsenal on the Atlantic coast and the disestablishment of the interior ones—Allegheny and Columbus—will leave, it is believed, too great an area of country between the Atlantic coast and the Rock Island Arsenal (the proposed arsenal and armory of the valley of the Mississippi) unprovided with an ordnance depot, and hence the board recommend the retention of the Indianapolis Arsenal as one for storage and issue to meet the wants of the northern-lake frontier and the central portion of our country lying to the immediate west of the Atlantic States. Indianapolis is a great railroad center; its other facilities are prominent, and the present arsenal at this point has, in its substantial and capacious store-houses and other advantages, all that is needed for the purpose required.

"In order to inaugurate this general plan for concentration the board recommend that Congress be asked to make the necessary appropriations for the immediate purchase of the site for the grand arsenal proposed, and for the erection of suitable buildings immediately required thereon, and to enact a law authorizing the sale of the arsenals above designated.

"The arsenals that can be soon prepared for disposition are Washington, Allegheny, Columbus, Detroit, and Pikesville. The following arsenals should be disposed of at such times as the stores now manufactured at them can be provided for at the grand arsenal, viz: Watertown Arsenal, Massachusetts, and Watervliet Arsenal, New York. It is apparent that no sales should be made until the Department is fully prepared elsewhere to replace the facilities lost by the disposal of any of our arsenals.

"It is evident that any judicious plan for the disposition of even those arsenals most available at present for sale, under the above-proposed arrangement of the ordnance facilities for the United States, would require two or three years for consummation, and hence the necessity of appropriations by Congress to secure the site for the contemplated 'grand arsenal,' and its preparation for buildings; the erection of some, and the making of improvements required at its initiation, cannot but be apparent.

"It should be provided by law that the net proceeds of all sales of our arsenals should be used in building up the 'grand arsenal.' The present estimated cost of the arsenal-site and adjacent proof-ground is $262,275.

"To purchase this site and to provide for improvements and buildings which should and can be provided during the first year, it is recommended that Congress be asked at its next session for an appropriation adequate to secure the site and proof-ground, and an additional sum, not exceeding $500,000, for such improvements and structures as the Department may deem best and most expedient to at first provide.

"The accompanying statement, prepared from the reports of the commanding officers, appended, marked AA, shows an estimated return from the sale of those arsenals which can be most readily prepared for disposition at present, (if the proposed plan is adopted,) in the aggregate of $2,109,590.56, and that the proceeds of the two remaining ones,

Watertown and Watervliet, whose disposition must be at least delayed until they are fully superseded by the proposed new arsenal, will be $1,414,237. Valuable machinery now on hand at the arsenals recommended to be sold and dismantled can be utilized at the 'grand arsenal.' The grand aggregate resulting from the contemplated sales will be $3,526,827.56. This amount will undoubtedly go far toward, if not be entirely adequate for, the full accomplishment of the contemplated concentration of our ordnance manufactures and facilities, and at a point whose superior local, geographical, and other advantages seem to demand centralization; and when we consider the undoubted improvements to be attained, the ease with which they can be secured, and the prospectively small outlay required, it is believed that sound judgment and a wise economy will point to the importance of an early accomplishment of this proposed distribution of the duties of the Ordnance Department of the United States.

"No material changes in values of grounds, buildings, or other appointments of our arsenals have occurred since the date of the above-quoted report, and the status remains the same, save that the Columbus and Detroit arsenals have passed from the control of the Department, the former having been turned over to the recruiting service, and the latter to the Department of the Interior. This leaves the arsenals and armories east of the Mississippi as follows:

Kennebec Arsenal, Augusta, Me.
Watertown Arsenal, Watertown, Mass.
Springfield Armory, Springfield, Mass.
Watervliet Arsenal, West Troy, N. Y.
New York Arsenal, Governor's Island, N. Y. H.
Pikesville Arsenal, Pikesville, Md.
Frankford Arsenal, Philadelphia, Pa.
Washington Arsenal, Washington, D. C.
Fort Monroe Arsenal, Old Point Comfort, Va.
Augusta Arsenal, Augusta, Ga.
Indianapolis Arsenal, Indianapolis, Ind.
Allegheny Arsenal, Pittsburgh, Pa.

"The present absolute needs of the service demand, in the judgment of the board, all the manufacturing facilities of the Springfield Armory, Frankford, Watervliet, Watertown, and Fort Monroe arsenals, for the production of warlike stores, and the remaining ones, Kennebec, New York, Washington, Augusta, Indianapolis, and Allegheny, are required for their present uses, to wit: care and preservation, issue and receipt, and repair of ordnance and ordnance stores.

"It will be seen that but one arsenal (Pikesville) remains as not necessary for the wants of the Department. Its estimated value is $46,635. It should be sold.

"The board, from the above, therefore deems the retention of all our arsenals east of the Mississippi, except Pikesville, as essential for the necessities and proper service of the Ordnance Department, and strongly recommends that no other arsenal be disposed of by sale or otherwise, unless it becomes feasible, by congressional legislation, to carry out the plan of concentration in the manner proposed by plan No. 1, of the report of the Board on Arsenals of 1874. In concluding this report, the board, concurring to the fullest extent in plan No. 1 of the report of the Board on Arsenals of 1874, would earnestly urge on the Department the wisdom and economy of the concentration of ordnance manufactures and other facilities as proposed by that plan, and recommends its favorable indorsement by the proper authorities for congressional action.

OPINIONS AND RECOMMENDATIONS OF THE BOARD.

"Rome, Ga., as a proposed site for a United States arsenal for the South:

"The geographical position of the mountainous region of Northwestern Georgia, the general healthfulness of this part of the South, and its great natural advantages in mineral wealth and agricultural resources, render this section of our country prominent for the location of sites for manufacturing purposes, especially those devoted to such fabrications as are needed for ordnance uses.

"Rome, well located at the confluence of Oostanaula and Etowah, forming the Coosa branch of the Alabama, has a well-developed railroad system connecting it with the great trunk-roads of the United States, and by the contemplated improvements of its water-courses can be connected by this mode of transit with the Gulf of Mexico. The resources of the immediate surrounding country in iron-ores, and the means of its reduction into charcoal pig, its agricultural and manufacturing advantages, its availability in sites for workshops and other essential features for an industrial establishment, are additional elements in its favor.

"While, however, acknowledging its merits in the above regards, yet its geographical position and rail and water communications (prime and essential features in location) are, in the opinion of the board, inferior to those of the Augusta Arsenal, Ga. The latter, being already located and provided with suitable buildings, has all the prime requisites for a southern arsenal for storage and repairs, and the board cannot, therefore, favorably recommend at this present juncture its abandonment and the provision of a new arsenal at Rome, Ga.

"S. CRISPIN,
"*Bvt. Col. U. S. A., Lieut. Col. Ordnance, President of the Board.*
"T. J. TREADWELL,
"*Major of Ordnance.*
"T. G. BAYLOR,
"*Major of Ordnance, Recorder.*"

OPINIONS AND RECOMMENDATIONS OF THE BOARD OF OFFICERS CONVENED BY ORDERS OF THE CHIEF OF ORDNANCE, DATED NOVEMBER 12, 1873.

* * * * * * *

"On the best method of concentrating the manufacturing operations of this Department east of the Mississippi River, either by the establishment of a grand arsenal on the Atlantic seaboard or the enlargement of, and concentration of work in, one or more of our arsenals, discontinuing the remainder of the arsenals, or retaining one or more as mere places of deposit."

PLAN 1.

"The Ordnance Department, for nearly the last thirty years, in the performance of the various duties intrusted to it by law, under the Secretary of War, in the manufacture and procurement of all ordnance and ordnance stores for armies called into the field at different times during this period, also in the providing of warlike stores for the prospective

wants of future armies, the armaments and material for sea-coast defenses, the material for arming and equipping the militia, and the performance of the important experimental duties intrusted to its care, has experienced during this period more or less serious embarrassment, not only from the inadequacy of existing facilities at the present arsenals of construction, but from their locations and limited resources, necessitating the conduction of the manufacturing operations at different points, widely separated, and being more or less objectionable on account of transportation, procurement of labor and material, and at the loss of the evident economy of a judicious concentration of ordnance manufactures.

"Our present arsenals of construction, located between the Mississippi River and Atlantic Ocean, are widely scattered from Maine to Georgia. This policy of location was necessary at the time of their establishment, when but few, if any, railroad means of transit existed in our country, and when it was important, from this cause, that equipment of troops should be made at or near the localities where raised.

"But at the present day, when our elaborate and perfected railroad and telegraph systems of communication have rendered the question of distance one of but secondary importance, we can now take advantage of these improvements, and subserve the true interests of economy, perfect our products, and attain the other manifest advantages of a policy of centralization by a concentration at one grand arsenal of the most important manufacturing operations in the Department.

"The great importance of carrying out this policy at a 'grand arsenal on the Atlantic seaboard' has been fully recognized and urged in the report of the Chief of Ordnance of December 3, 1862, and repeatedly pressed upon the notice of the War Department, and the action of Congress earnestly recommended in the subsequent annual reports of this Office from 1869 to 1873.

"The first consideration in the location of an arsenal of construction, to effect these ends, is evidently, that it should occupy a comparatively central geographical position with respect to the Atlantic seaboard, and have at command the facilities of one of our great commercial centers.

"The pre-eminence of the city of New York, in its gigantic means for transit and for prompt distribution of all warlike stores to all points of the United States, its unsurpassed resources in labor and material, and its advantages in a geographical point of view over any city on our coast as a distributing-point, renders the location of an arsenal-site in its vicinity, if practicable, of the greatest importance; and, accordingly, the board has directed its examination particularly to this section of the country.

"A consideration and examination of the surroundings of New York point conclusively to the immediate north of Newark, N. J., as the section of country possessing the best advantages, and as being most eligible and desirable for locating the proposed arsenal.

"The land here, bordering on the Passaic River, rises from the level of the river to a height of over 100 feet, and then gradually slopes eastward to the meadow-lands bordering on the Hackensack.

"The character of the ground gives it natural features of defense, and this, added to its location (see Map 1) with respect to important works of defense of New York Harbor, and its freedom from the possibility of naval attack, are considerations of the highest importance.

"The diverging main lines of railroad from Jersey City and Hoboken, at present eleven in number, bring this site in close and rapid communication with New York and the country at large, and the water-facilities of the Passaic and Hackensack are available for transportation

of supplies to and from the harbor of the commercial metropolis of our country.

"A special site on this ground has been selected and surveyed (see report of Mr. H. N. Babcock marked L") and is represented in detail on map marked 2.

"Its location with respect to New York City; Newark, and the surrounding country, also with respect to railroad and water means of transit with New York, is shown by the accompanying map, marked 3.

"It will be seen (Map 3) that this site is distant about * * * from New York, and about three miles from the suburbs of Newark. It has a frontage on the Passaic of * * * * * , and extending eastward, as it does, from the Passaic River to the Hackensack meadows, it thus has access to both rivers.

"A short line of railroad * * * will connect the site with the railroad system of the country, and at a slight cost of construction, owing to the level character of the adjacent lands.

* * * * * * *

"A suitable proof-ground for ordnance adjoining the arsenal-site is shown on Map 3, and marked (PG.) * * * It would constitute a valuable adjunct to the arsenal, and it is recommended that it be secured, if the site for the latter be approved and purchased.

"The above-recommended purchases do not provide for storage depots on the waters of New York Harbor, to be specially utilized in times of war. Our recent past experience in the rebellion has shown that such facilities can be readily extemporized when needed from buildings and wharfages already existing for ordinary commercial purposes in New York Harbor, and at a less cost than would be incurred in their permanent provision by the Government.

"It would appear from the above considerations and facts, that a 'grand arsenal' of construction can be located, at a reasonable and moderate cost, on the Atlantic coast, and at the most desirable point for the concentration of ordnance manufactures.

"In view of this fact, there remains to be considered and determined the proper distribution of the duties of the Department, based upon the early establishment of this arsenal, and the proper disposition of such arsenals as its erection will render no longer needed for the services of the United States.

"The arsenals and armories now established east of the Mississippi River are as follows, to wit:

Kennebec Arsenal, Augusta, Me.
Watertown Arsenal, Watertown, Mass.
Springfield Armory, Springfield, Mass.
Watervliet Arsenal, West Troy, N. Y.
New York Arsenal, Governor's Island, New York Harbor.
Pikesville Arsenal, Pikesville, Md.
Frankford Arsenal, Philadelphia, Pa.
Washington Arsenal, Washington, D. C.
Fort Monroe Arsenal, Old Point Comfort, Va.
Augusta Arsenal, Augusta, Ga.
Indianapolis Arsenal, Indianapolis, Ind.
Columbus Arsenal, Columbus, Ohio.
Allegheny Arsenal, Pittsburgh, Pa.
Detroit Arsenal, Detroit, Mich.

"The principal manufacturing operations of the Department are now performed at the following arsenals, to wit: Watertown, engaged in the production of sea-coast carriages and projectiles for heavy guns; Spring-

field Armory, in the manufacture of small arms; Watervliet, in the manufacture of leather-work; Frankford Arsenal, in small-arm ammunition, and Fort Monroe Arsenal, in sea-coast carriages and on experimental duties. The remaining arsenals in the above list are either engaged in small repairs or are simply storage-depots for the care and preservation, issue and receipt, of ordnance and ordnance stores. It is believed that, except small-arms and small-arm ammunition, the more important ordnance and ordnance stores, more especially those for field and siege artillery and those to be provided for the use of our sea-coast defenses, such as cannon, heavy sea-coast carriages, projectiles, and ammunition, and other stores and appliances for their service and maneuver, also harness and the more elaborate articles of leather-work, should all be made at the grand arsenal of construction.

"The manufacture of our small-arms and small-arm ammunition for our present armies and militia, and for our reserve supply, is one of the greatest importance; and as the Springfield Armory is a model one of the world in the perfection of its fabrications, and the extent and completeness of its arrangements and facilities for the production of this class of warlike stores, the board regards the retention of this establishment as a foregone conclusion, in its proposed plan for concentration, for the fabrication of its present specialty, and such other work as its facilities may accommodate. Recognizing also the almost imperative necessity, in order to secure perfection in production in the fabrication of small-arms and small-arm ammunition, that they should be produced side by side, the board is of the opinion that arrangements should be made for the transfer of the present manufacturing operations of small-arm cartridges at Frankford Arsenal to the Springfield Armory as early as it can be accomplished with economy and with a due regard to other important public interests. The more simple leather-work fabrications of infantry and cavalry accouterments, and perhaps some other kinds, all demanded in quantity, and requiring little but no special appliances for their manufacture, can, it is thought, be economically and judiciously made at one of our present arsenals. The board recommends the retention of the Frankford Arsenal for this purpose. Its geographical position and its facilities of shops and store-houses and for material and labor of the kind required, its means of transit and its close and quick connection with the proposed grand arsenal at Newark, N. J., point conclusively to its retention for the purpose suggested, and as part of the proposed plan for concentration.

"It will be seen that the design contemplated by the board is to concentrate all the principal manufacturing operations of the Department at the proposed grand arsenal, the Springfield Armory, and at Frankford Arsenal.

"It remains now to designate those arsenals which it is proposed shall be retained to meet the wants of the country as arsenals for storage and repair, and those to be used simply as depots for the care, preservation, receipt, and issue of warlike stores.

"A careful and mature consideration of the question leads the board to recommend the retention of the following arsenals, to wit: Augusta and Fort Monroe as arsenals of storage and repair, and Kennebec, New York, and Indianapolis Arsenals as depots for storage and issue. This will leave to be sold the Watertown, Watervliet, Pikesville, Washington, Allegheny, Columbus, and Detroit Arsenals.

"The reasons for the retention of the above arsenals, as recommended by the board, are as follows, to wit:

"*Augusta Arsenal.*—This is the only arsenal left in the entire South,

east of the Mississippi, and the nearest constructing arsenal to it in the proposed plan will be nearly eight hundred miles distant. Its retention and improvement, and sufficient enlargement to render it adequate to supply the needs of the Department in the South, in the opinion of the board, is a matter of wisdom and in fact a necessity. The proposed improvements and enlargement (see memorandum letter of board addressed to Captain Hill, March 7, 1874, official copy of which was sent to that officer March 16, 1874, and the report of that officer, dated March 16, 1874,) can be secured at a moderate cost. Its present workshops and buildings are in excellent condition, are sufficiently large in plan to be utilized almost without cost in the remodeling of the arsenal as one for storage and repair. The location, inland, is one of the best in the South, both geographically and in its rail and water facilities, for the reception and distribution of supplies for the South. These and its other advantages for the purposes required, (see Captain Hill's report,) and its general healthfulness, further confirm the board in its opinion as to the propriety and necessity of retention of the Augusta Arsenal. Its general plan and its location with respect to Augusta City is given in the accompanying map, marked 4.

"*Fort Monroe Arsenal, Virginia.*—This arsenal is located on a Government reservation, and its connection with Fort Monroe renders its sale impossible. It is well provided with shops and machinery, and is admirably situated geographically on the waters of Hampton Roads for fitting out expeditions, as was shown in the late war.

"The arsenal as it now exists, however, is considerably scattered over the Government reservation, and as a matter of economy and efficiency it is recommended by the board that all the arsenal property inside the fort, consisting of quarters, barracks, and office, be turned over to the garrison of Fort Monroe. The store-houses and other temporary buildings should be torn down and the materials applied, as far as practicable, to the erection of suitable structures rendered necessary by this action, outside the fort in the vicinity of its shops. The necessary buildings required to be erected by this plan would cost but little additional to the value of the material obtained by the removal of the store-houses and buildings inside the fort. The buildings inside the fort should not be abandoned or turned over until their places are supplied by suitable structures contemplated to be erected outside the fort.

"*Kennebec Arsenal.*—This arsenal is situated on our northeastern frontier, bordering on Canada, is well located, has the requisite facilities, and is deemed necessary for retention to supply the present and prospective wants of that section of our country.

"*New York Arsenal.*—This arsenal, located on the glacis-slope of Fort Columbus, Governor's Island, is not available for sale. Whilst incapable of and having no manufacturing facilities, yet it has comparatively extensive storage capacity and wharfage, and superior facilities, from its location in New York Harbor, for the distribution of supplies, and will thus form a valuable adjunct for storage in connection with the proposed grand arsenal.

"*Indianapolis Arsenal.*—The construction of a large arsenal on the Atlantic coast and the disestablishment of the interior ones—Allegheny and Columbus—will leave, it is believed, too great an area of country between the Atlantic coast and the Rock Island Arsenal (the proposed arsenal and armory of the valley of the Mississippi) unprovided with an ordnance-depot, and hence the board recommend the retention of the Indianapolis Arsenal as one for storage and issue to meet the wants of the northern-lake frontier and the central portion of our country

lying to the immediate west of the Atlantic States. Indianapolis is a great railroad center; its other facilities are prominent, and the present arsenal at this point has in its substantial and capacious store-houses and other advantages all that is needed for the purpose required.

"In order to inaugurate this general plan for concentration the board recommend that Congress be asked to make the necessary appropriations for the immediate purchase of the site for the grand arsenal proposed, and for the erection of suitable buildings immediately required thereon, and to enact a law authorizing the sale of the arsenals above designated.

"The arsenals that can be soon prepared for disposition are Washington, Allegheny, Columbus, Detroit, and Pikesville. The following arsenals should be disposed of at such times as the stores now manufactured at them can be provided for at the grand arsenal, viz: Watertown Arsenal, Massachusetts, and Watervliet Arsenal, New York. It is apparent that no sales should be made until the Department is fully prepared elsewhere to replace the facilities lost by the disposal of any of our arsenals.

"It is evident that any judicious plan for the disposition of even those arsenals most available at present for sale, under the above-proposed arrangement of the ordnance facilities for the United States, would require two or three years for consummation, and hence the necessity of appropriations by Congress to secure the site for the contemplated 'grand arsenal,' and its preparation for buildings; the erection of some, and the making of improvements required at its initiation, cannot but be apparent.

"It should be provided by law that the net proceeds of all sales of our arsenals should be used in building up the 'grand arsenal.' The present estimated cost of the arsenal-site and adjacent proof-ground is $262,275.

"To purchase this site and to provide for improvements and buildings which should and can be provided during the first year, it is recommended that Congress be asked at its next session for an appropriation adequate to secure the site and proof-ground, and an additional sum, not exceeding $500,000, for such improvements and structures as the Department may deem best and most expedient to at first provide.

"The accompanying statement, prepared from the reports of the commanding officers, appended, marked AA, shows an estimated return from the sale of those arsenals which can be most readily prepared for disposition at present, (if the proposed plan is adopted,) in the aggregate of $2,109,590.56, and that the proceeds of the two remaining ones, Watertown and Watervliet, whose disposition must be at least delayed until they are fully superseded by the proposed new arsenal, will be $1,414,237. Valuable machinery now on hand at the arsenals recommended to be sold and dismantled can be utilized at the 'grand arsenal.' The grand aggregate resulting from the contemplated sales will be $3,526,827.56. This amount will undoubtedly go far toward, if not be entirely adequate for, the full accomplishment of the contemplated concentration of our ordnance manufactures and facilities, and at a point whose superior local, geographical, and other advantages seem to demand centralization; and when we consider the undoubted improvements to be attained, the ease with which they can be secured, and the prospectively small outlay required, it is believed that sound judgment and a wise economy will point to the importace of an early accomplishment of this proposed distribution of the duties of the Ordnance Department of the United States."

PLAN 2.

"While the board is unanimous in the opinion that the foregoing plan will in the best and most satisfactory manner economize and perfect the manufactures of the Department, and otherwise provide for its wants east of the Mississippi, yet it feels called upon, under the orders convening it, to submit another arrangement for concentration, based upon the extension of the grounds and the enlargement of the manufacturing and storage facilities of one of our large arsenals of construction, in lieu of the establishment of a new one.

"The board finds this a difficult, if not impossible, problem to satisfactorily solve, owing to the want of a decided pre-eminence in the important essentials requisite at any one of our present arsenals of construction. The one best adapted for this purpose and possessing greater advantages than any other, from its central geographical position with respect to the Atlantic coast, (see map marked No. 23,) easy and ready procurement of labor and material, and from its facilities for storage, transportation, and distribution of its products, is the Frankford Arsenal. Its enlargement is practicable, as the adjoining farms (see appended map, marked 5, and report of the commanding officer) can be purchased.

* * * * * * *

"The water-frontage of Frankford Arsenal on the Delaware can be made available for transportation, and the grounds can be readily connected by rail with the great railroad system of our country.

"Its geographical position is by no means as acceptable as the proposed site near New York City, and its extension would not in the highest degree provide for our wants; but yet it is the only establishment for the purpose that the board can in its judgment point to as entitled to consideration, with the view to enlargement and modification, to supply the place of a new grand arsenal of construction.

"In the event, however, of its contemplated enlargement, the board recommends that the Springfield Armory, in addition to its present uses and the manufacture of small-arm ammunition, have also transferred to it the manufacture of that class of leather-work contemplated in the first plan to be fabricated at Frankford Arsenal.

"This arrangement, as no other changes in the first plan proposed by the board are deemed advantageous, would leave, after the disposition of the arsenals heretofore recommended to be sold, the ordnance duties of the country to be performed at the following arsenals and armories, viz:

First. Frankford Arsenal, Springfield Armory—arsenal and armory of construction.

Second. Fort Monroe Arsenal, Augusta Arsenal—arsenals for storage, issue, and repair.

Third. Kennebec Arsenal, New York Arsenal, and Indianapolis Arsenal—arsenals for storage and issue.

"In concluding this part of the report, the board feels called upon to state that this second plan, in its judgment, offers no considerable advantages even on the score of economy, and, therefore, it feels constrained not to recommend its adoption unless it is impracticable to carry out the first plan or its equivalent.

"The accompanying maps, marked from 4 to 17, show the extent of the grounds and location of the buildings at our present arsenals east of the Mississippi. The geographical positions of the arsenals and their rail and water communications are shown on map No. 24.

POWDER-DEPOT SITES.

"The essential requisites for a powder-depot site are fully set forth in the instructions of the Chief of Ordnance to the board convened at New York City, dated October 6, 1866, to wit:

"'In selecting sites for these two depots, the following considerations must be observed:

"'1st. The depots should be in a region of country which does not admit of being densely populated, so that the destruction of life and property by accidental explosions would be as small as possible.

"'2d. They should be of sufficient extent to contain in suitable positions magazines to store not less than 10,000 tons of powder for the depot near New York, and not less than 6,000 tons for the other depot.

"'3d. They should be near to a principal railroad, that they may be readily connected with it by a railroad belonging to the Government, and at a point where transportation can be had with facility at all seasons to all points on the seaboard, to the interior, and to the lake frontier.'

"The board, although deeming it of the first importance that the powder-depot should be established near the contemplated grand arsenal of construction, yet in its surveys due attention was paid to important local particulars.

"The vicinity of New York, on the line of the Erie Railroad, it was known from the surveys of the board of 1866, could not only furnish sites in every way desirable for the proposed depot, but the best attainable in the country.

"The board made not only the surveys made by the board of 1866, but also additional ones.

"The special particulars of the sites selected to choose from are given in the accompanying maps marked from — to —, and their relative positions to the proposed grand arsenal are given in the accompanying map marked —.

"Regarding this subject, the board (concurring in the opinion and facts therein set forth) quote the following from the report of the board of 1866:

"'The location of a site for the depot to be established in the vicinity of New York City was deemed to be the first subject for consideration, and preliminary examinations of the most approved local maps—containing in minute detail the topographical features of the surrounding country and the different converging lines of railroad to New York—were made, and detailed inquiries instituted among parties possessing accurate and special knowledge of the characters of *special localities*.

"'A combination of immediate water and railroad facilities for transportation was regarded as a desideratum, but this condition, it was found, could not be fulfilled near New York without sacrificing the more important requirements of a site as set forth in the instructions of the Department.

"'The results of the preliminary inquiries and examinations of the board pointed decidedly and clearly to the valley of the Ramapo River, between the town of Sufferns, N. Y., and Turner's Station, N. Y., along the line of the Erie Railroad, and distant from New York from thirty-two to fifty miles, as the only general locality which had all the prime requisites, and would in all probability furnish the desired site. (See Map No. 18.) A *detailed examination* on the part of the board of this tract of country—extending from Sufferns to Turner's—was made. The general topographical features of this part of the Ramapo Valley were found to be hills on either side varying from 100 to 500 feet in height (the terminating slopes of the Taconic range) skirting the narrow bottom-lands on a

which the Erie Railroad is located, and here and there broken by narrow ravines diverging at different angles from the valley, and at intervals interrupted by broader ones, on some of which are located the small villages of Ramapo, and Sloatsburgh, and the hamlet of Southfields. In rear of these heights the country is broken by narrow ravines parallel to the valley and walled in by the opposite hills.

"'These superior natural features for our purposes, with the absence of inhabitants and of arable grounds for cultivation and support of a dense population, determined the question as far as general location was concerned, and the special examinations made led to the selection of a tract which, it is believed, will afford an excellent site, and one which we can specially recommend as having every requisite that could be desired, leaving out the advantages of immediate water-transportation. (See Map No. 18.) This site is known as the Augusta tract, situated in Orange and Rockland Counties, New York, and owned by Peter Lorillard, esq., of New York City. It is thirty-eight miles from New York, has an area of 4,481 acres, and is traversed by the Erie Railroad along the valley of the Ramapo. (See Map No. 1.)

"'That portion of the property west of the Erie Railroad, bounded on the east by the line extending from intersection of the northern line with the railroad southward through "Fox Hill," "High Peak," and "Ant Ridge," and bounded on the west by the property of Mead and Shuet, and on the south and north by the 'Sterling estate,' has been selected (an area of about 2,500 acres) as the best adapted to our purposes. (See Map No. 1.) This portion of the tract is approached by the wood-road intersecting the "Orange turnpike" at the "saw-works," and leading through a narrow valley to the "fish-house," and extending thence along the east shore of Truxedo Lake. A high hill, around the base of which the road winds, guards this approach at the "saw-works."

"'The line of hills skirting the valley of the Ramapo, of which "Fox Hill," "Ant Ridge," "High Peak," and "Iron Mine" are prominent points, and the range bordering on Truxedo Lake and its outlets on the west, form, it will be seen, material barriers on the exterior; and as the intervening or interior ground is broken by ravines, and affords natural traverses between which to locate magazines, we have thus all the natural advantages which could possibly be desired.

"'As the fall from Truxedo Lake along the valley of the outlet is only 80 feet to the saw-works, it will be seen that a railroad to connect with the Erie Railroad at this point can be readily constructed, and thus connect the site with the interior by rail, and with New York City direct by rail, or, via Piermont, by rail or rail and water. The nearest hamlet to this property is Southfields, a wood and water station of the Erie Road, four miles off; the nearest village is Sloatsburgh, two miles below. (See Map No. 1.) The ground is rocky, and this, combined with its hilly nature, renders it unsuited for agricultural purposes, for residences, or for manufacturing settlements.'

"The Augusta tract, however, from the present views of the owners, (see letters of Mr. Lorillard, marked B′ and K″,) may be too costly to enable the Government to secure it, and the board extended its examination, and selected and had surveyed, as next best and available for the purpose, the sites shown in detail in the accompanying maps, alluded to heretofore.

"These sites, * * * in the general features of seclusion, character of ground—inclosed by their hilly barriers—ease of connection with the Erie Road, and other essentials, approach the perfection of the Augusta tract sufficiently near to render them available for our purpose, provided the former cannot be secured at a reasonable price. In any event

the board deem, from the results of its general surveys, that the securement of a suitable site in this section is a foregone conclusion.

* * * * * * *

"In concluding this part of the report, it is deemed well to allude to the immediate necessities of a suitable powder-depot for the Atlantic coast.

"In the establishment of our present arsenals, as their locations, at the time of their construction, were but sparsely settled, the erection of powder-magazines on these Government reservations provided for our wants in this respect. The rapid increase of population in the adjacent towns and cities has, however, in the majority of cases, rendered these magazines dangerous to the communities in which they are located, and hence the Government either has abandoned or eventually will have to essentially abandon the storage of powder at all of our arsenals. The damp sea-air renders our fortifications unfitted for this purpose, and the Government has now large quantities of powder rapidly deteriorating at these places for want of proper storage-facilities. About 2,500 tons of powder and 3,000 tons of niter are now on hand.

"The necessity of immediate action is hence deemed, it is believed, apparent, and it is earnestly recommended that Congress be asked at its next session to appropriate a sum adequate to purchase a site, and commence the provision of buildings suitable not only for the storage of powder, but also for our niter supplies, and the accommodation of suitable machinery and appliances for the manufacture of experimental powders.

EXPERIMENTAL GROUND FOR HEAVY ORDNANCE.

"The Department has long felt the want of a suitable site for testing heavy ordnance, obtaining ranges, and solving the various experimental problems connected with the science of gunnery.

"The report of the Chief of Ordnance of 1872 thus alludes to the entire inadequacy of our present facilities in this regard:

'It has been compelled to avail itself of the limited extent of ground near Fort Monroe for the prosecution of these important duties. As the artillery-school of practice is established on this reservation, the space is necessarily too contracted for the operation of both. Besides, the range obtained on land is but little more than a mile, and that over the waters of the Chesapeake Bay seldom available; whereas, for efficient experimental purposes, a range of at least six miles is indispensable.

"'Some central point convenient to railroad communication, with a suitable extent of level ground, could be readily selected and purchased at a small cost. Experiments with large ordnance cannot be properly conducted without the best and most approved facilities, such as every military nation has found it necessary to provide.'

"The main features that are essential to such a site are that it should be comparatively level, easily accessible, not traversed by highways or extensive water-courses, uninhabited, and sufficiently remote from any settlements to avoid any possible accidents, and embracing an extent of land from seven to eight miles in length and from one-half to one mile in width. It is deemed very desirable by the board that this site should not be very remote from the grand arsenal on the Atlantic seaboard, nor from the powder-depot.

"The level beaches and flat interior lands of Long Island and the coast of New Jersey were all, it will be seen by the record, examined.

"The sites examined on Long Island are in the vicinity of Babylon, Deer Park, Bay Shore, and Islip. The ground lies here in extensive level stretches, adapted in this respect for our purposes, but it is deemed

objectionable by the frequency of rail and wagon roads, and by the rapidly-increasing settlements, rendering early and serious interference in this regard highly probable.

"The Jersey coast, extending from Sandy Hook to and including Squan and Island Beaches, consists of level and long stretches of sandy beaches, and the upper end of Squan Beach, in the vicinity of the town of Point Pleasant and Squan Village, has the best local advantages found and examined by the board. This ground has been carefully surveyed, under the direction of the board, by Mr. H. N. Babcock, (see his report marked M',) and a site selected. (See Map marked 21.)

* * * * * * *

"The contemplated rail connection would be about two and one-half miles, and its construction would not require any extensive excavation or filling in, and hence it can be built at a moderate cost.

"The relative location of this site to the grand arsenal and the proposed powder-depot is shown on the accompanying map marked No. 1. An examination of this map will show that ample rail facilities connect this section of the country with the country at large. The present United States life-saving and signal stations located on the beach, it is believed, will be advantageous to our use of this ground for experimental purposes, while our occupancy will not interfere with these other branches of the public service. The meteorological phenomena of this portion of the coast, such as the force, direction, and frequency of winds and occurrence of fogs, have not yet been fully determined, but all the information in this regard which the board could obtain is presented in the accompanying reports.

"While this site does not possess in the highest degree all the desired requisites, still it is believed to be the best that can be found on the Atlantic coast within a convenient and desirable distance from New York City, the proposed grand arsenal and the depot for powder.

"The purchase of this site, building the proposed railroad, and purchase of right of way, the erection of the necessary buildings and improvement of the ground, it is thought, will not exceed $100,000, and it is earnestly recommended by the board that Congress be urged to make the necessary appropriations at its next session.

"The Government reservation at Sandy Hook, (see map marked No. 22,) at the entrance of the harbor of New York, distant eighteen miles from the city, and in close and quick communication with it, has an available extent in length of, say, one to two miles, and in breadth of, say, three-fifths of a mile. Its general features are the same as Squan Beach, but it is entirely too contracted for all our uses, and the Long Branch Railroad limits and materially interferes with its usefulness as an experimental firing-ground. However, it is superior in geographical location and equal in other respects to our present facilities at Fort Monroe, and in the interim of the establishment of the experimental ground at Squan Beach it could be utilized, (with the permission of the Engineer Department,) as an adjunct with Fort Monroe, for carrying on such experiments and proof as it may be fitted for and as may be deemed desirable to have conducted at this point.

"S. CRISPIN,
"*Bvt. Col. U. S. A., Major of Ordnance, President.*
"T. J. TREADWELL,
"*Major of Ordnance.*
"T. G. BAYLOR,
"*Major of Ordnance, Recorder.*"

NOTE.—The maps and drawings referred to in the foregoing report do *not accompany* it. They are filed in the office of the Chief of Ordnance.

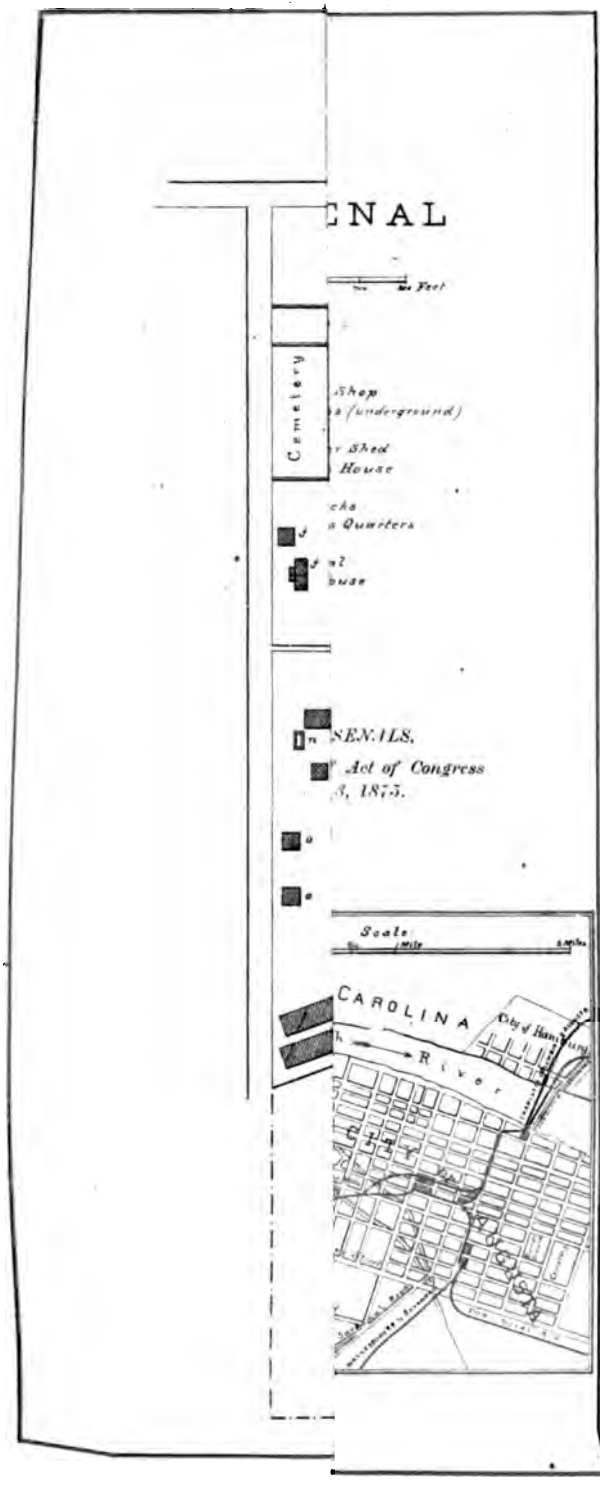
Statement of the original cost and the estimated market-value of lands, buildings, and improvements at the herein-named United States arsenals east of the Mississippi River.

Name of arsenal.	Original cost of land, buildings, and improvements.			Estimated market-value of lands, &c., as taken from reports of the respective commanding officers.			Remarks.
	Land.	Buildings, &c.	Total amount of cost of land, buildings, &c.	Land.	Buildings, &c.	Total estimated value of lands, buildings, &c.	
Allegheny Arsenal...	$19,383 71	$287,645 00	$307,028 71	$900,000 00	*$71,911 25	$971,911 25	The buildings, in the event of the land being sold in lots, would be of but little more value to the purchasers than for their materials, excepting those in the lower yard for railroad and manufacturing purposes, shops, dwellings, and store-houses.
Pikesville Arsenal...	(†)	Not given.	.....	11,935 00	34,700 00	46,635 00	The buildings, if sold without the land, would not bring over $5,000 to $7,000.
Washington Arsenal.	118,079 97	619,801 21	737,881 18	881,044 31		881,044 31	A board of assessors, appointed by the Secretary of the Interior, in their report, dated March 30, 1872, appraised the lands and buildings at this post at $1,527,850.
Watertown Arsenal..	53,616 13	473,286 63	526,902 76	120,000 00	310,000 00	430,000 00	The amount paid for the purchase of the two first tracts of land is not included in the original cost of the land at this post, as it could not be ascertained from the records of the office. The area of these two purchases is about forty acres. If the sale was forced, the buildings would not bring the price named.
Watervliet Arsenal‡.	56,769 27	545,620 00	602,389 27	150,000 00	837,234 00	987,234 00	In the event of the land being cut up into lots, some of the buildings would have to be moved from the streets, which would run through the grounds. In the letter, (extract-copy inclosed in letter to Board on Arsenals, &c., of April 1, 1874, marked "D³, to the Hon. John Coburn, chairman of Military Committee House of Representatives,") Col. P. V. Hagner states that he estimates that the reservation, laid out into lots 120 by 50 feet, should be worth about $400,000, excluding buildings.

* This value, being twenty-five per cent. of the original cost, is placed by the Board on Arsenals, &c.

† No record of cost on file at the post.

‡ The original cost of buildings and improvements is not given in many instances, hence the apparent difference between the estimated market-value and the original cost.


ENAL
Cemetery
Shop
(underground)
Shed
House
Quarters
SENALS.
Act of Congress
3, 1875.
Scale
CAROLINA
River

No. 4.

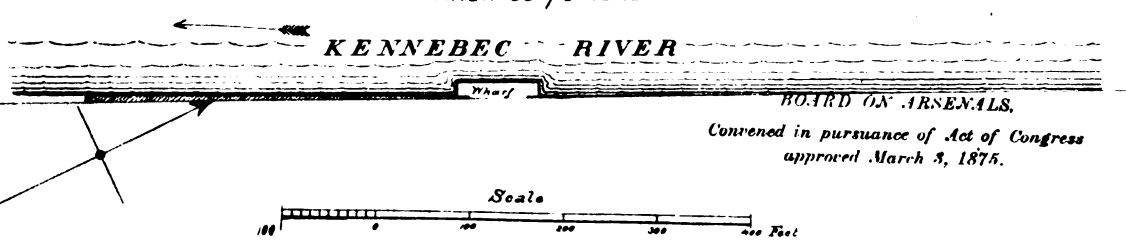
BOARD
Convened in pursu
approved
acres.
DARK RUN LANE
Mansion
RIVER
AWARE
STREET
Scale
Feet.

No 5.

No. 6.

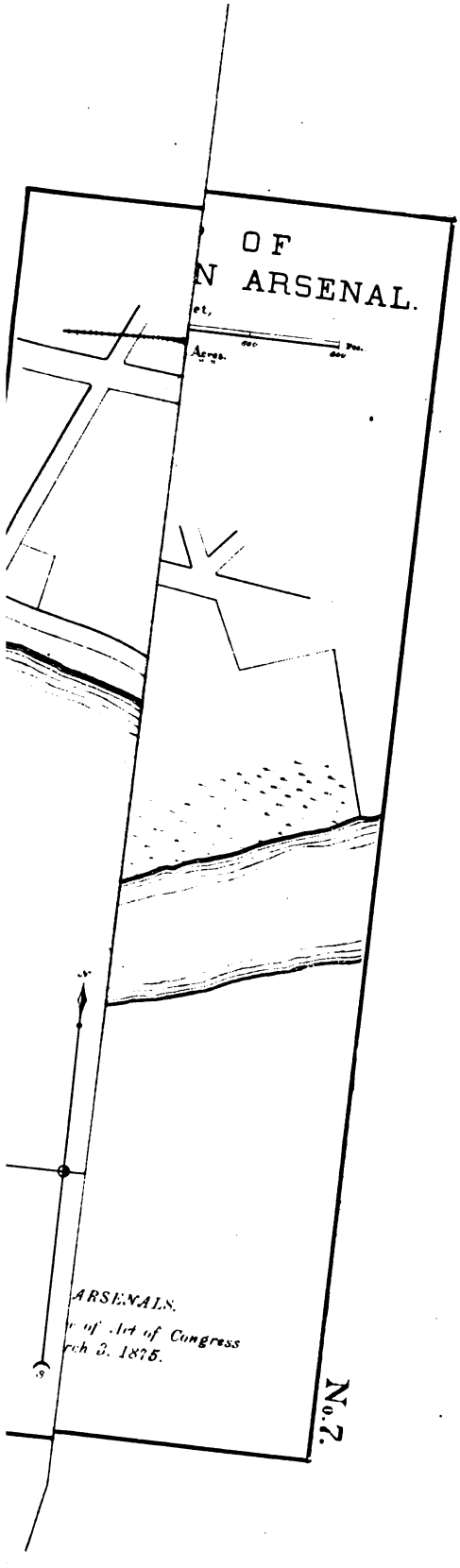
MAP OF
KENNEBEC ARSENAL, AUGUSTA, MAINE.

AREA 39 7/8 ACRES.



BOARD ON ARSENALS,

Convened in pursuance of Act of Congress approved March 3, 1875.



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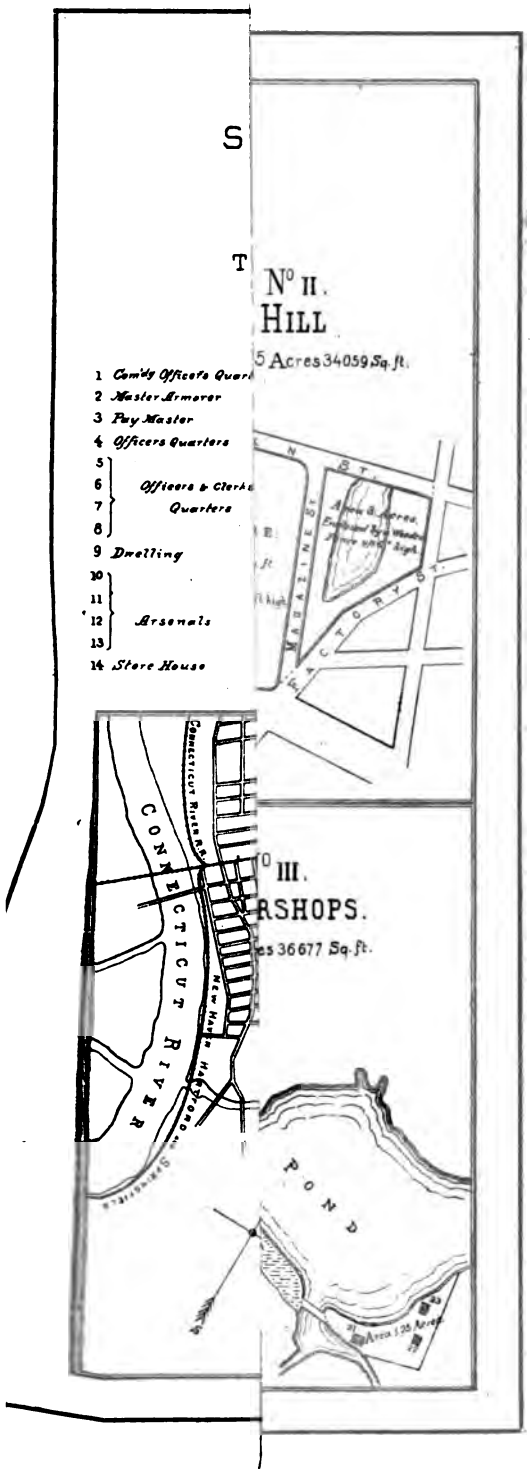
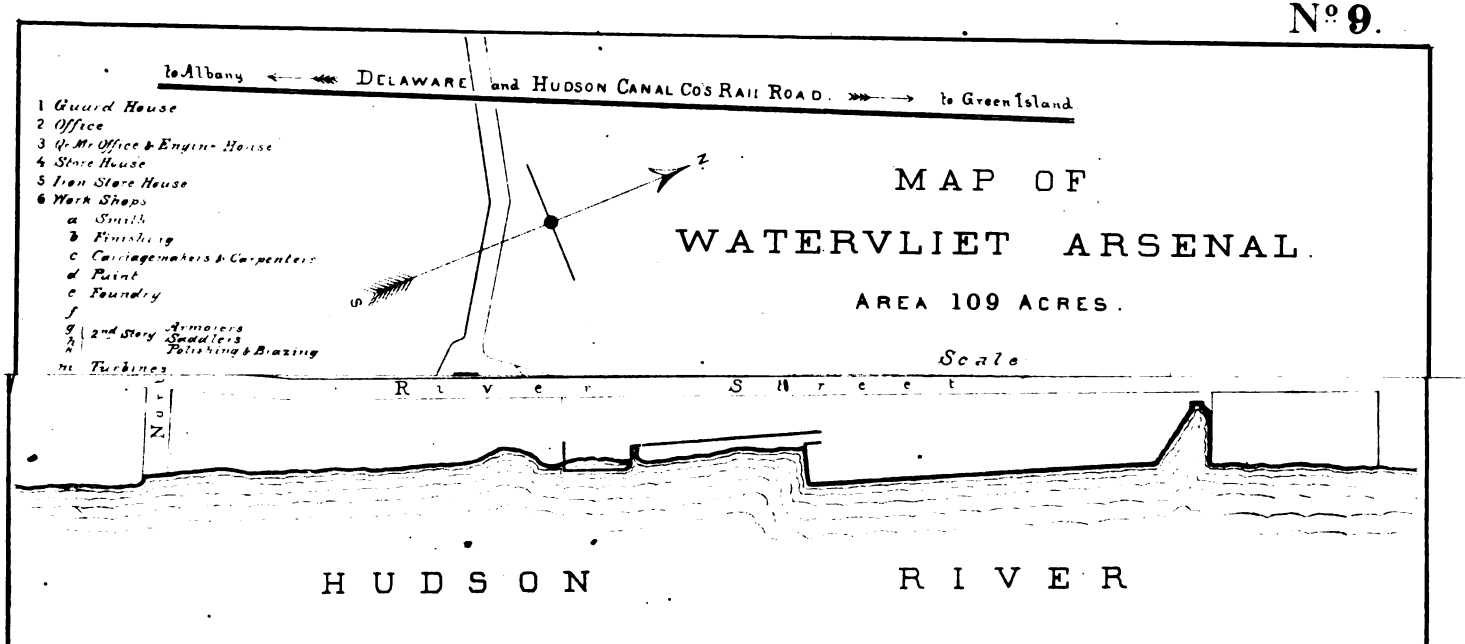

S
T
N° II.
HILL
5 Acres 34059 Sq. ft.
1 Com'dy Officers Quart
2 Master Armorer
3 Pay Master
4 Officers Quarters
5
6
7
8
Officers & Clerks Quarters
9 Dwelling
10
11
12
13
Arsenals
14 Store House
MAGAZINE ST.
CADRY ST.
CONNECTICUT RIVER
CONNECTICUT RIVER R.R.
N° III.
RSHOPS.
es 36677 Sq. ft.
New Haven Hartford & Springfield R.R.
POND

No. 8.

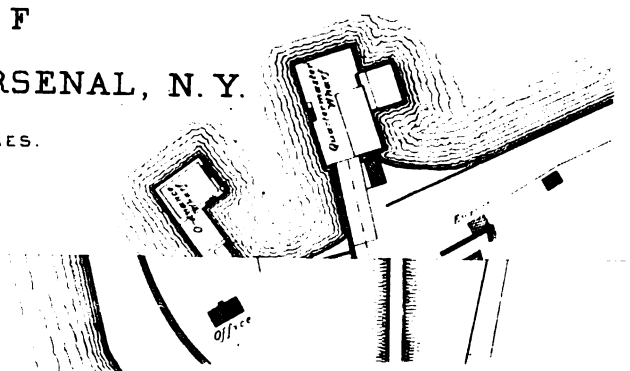
No. 9.


to Albany
DELAWARE and HUDSON CANAL CO'S RAIL ROAD.
to Green Island
1 Guard House
2 Office
3 Q. Mr Office & Engine House
4 Store House
5 Iron Store House
6 Work Shops
a Smith
b Finishing
c Carriage makers & Carpenters
d Paint
e Foundry
f
g 2nd Story Armorers
h Saddlers
n Polishing & Blazing
m Turbines
N
S
MAP OF
WATERVLIET ARSENAL.
AREA 109 ACRES.
Scale
River Street
HUDSON RIVER

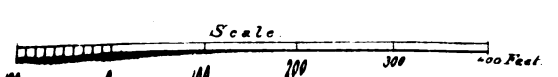
№ 10.

MAP OF NEW YORK ARSENAL, N. Y.

AREA 7.296 ACRES.



BOARD ON ARSENALS,
Convened in pursuance of Act of Congress approved March 3, 1875.



№ 11.

MAP OF
PIKESVILLE ARSENAL, MD.

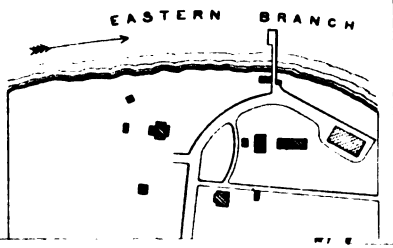
AREA 14 ACRES 147 RODS.

Scale

100 50 0 100 200 300 Feet.

BOARD ON ARSENALS.
Convened in pursuance of Act of Congress
approved March 3, 1875.

No. 12.

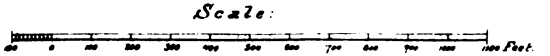


MAP OF
WASHINGTON ARSENAL, D. C.

AREA 69 ACRES.

BOARD ON ARSENALS,
Convened in pursuance of Act of Congress approved March 3, 1875.

Scale:



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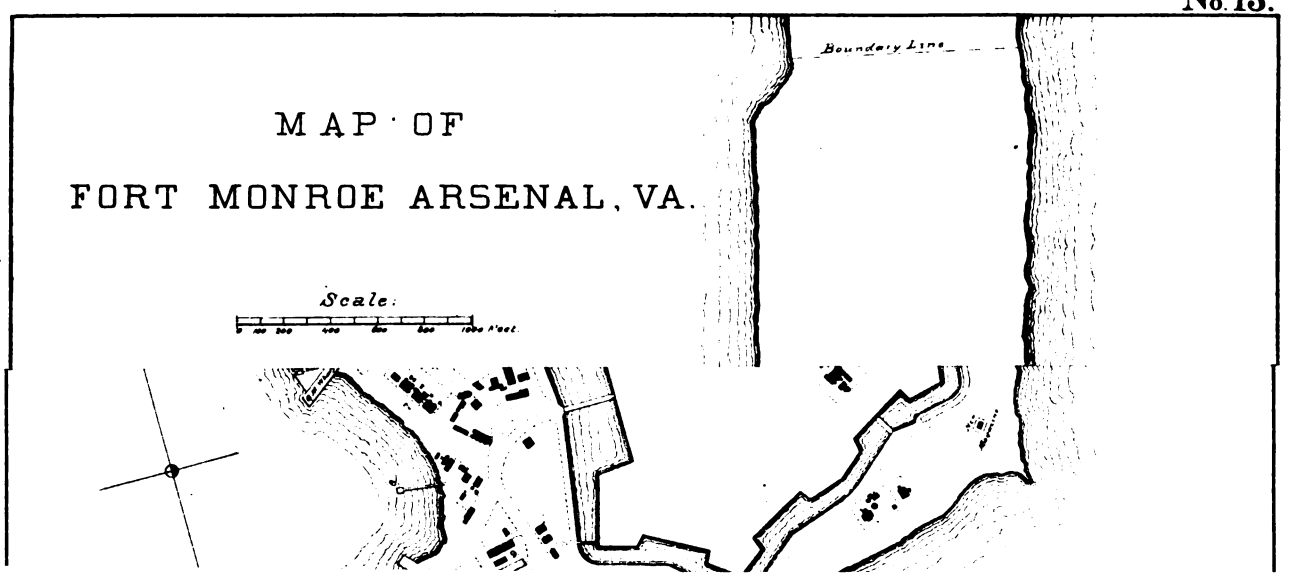
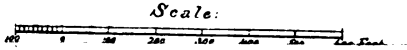


No. 14.

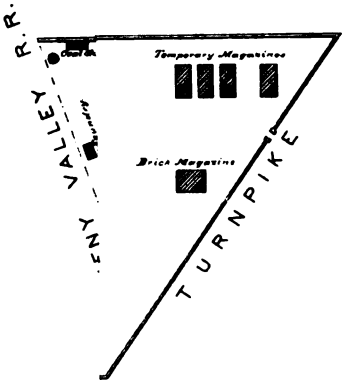
MAP OF
INDIANAPOLIS ARSENAL.

AREA 75.14 ACRES

Scale:



BOARD ON ARSENALS,
Convened in pursuance of Act of Congress
approved March 3, 1875.



SENALS,

Act of Congress
3, 1875.

No 16.

APPENDIX Q.

[House Ex. Doc. No. 158, 44th Congress, 1st session.]

Infringement on patents.

LETTER FROM THE SECRETARY OF WAR, TRANSMITTING LETTER, &C., FROM CHIEF OF ORDNANCE ON HOUSE BILL 2865, RELATING TO INFRINGEMENT ON PATENTS.—APRIL 12, 1876, REFERRED TO THE COMMITTEE ON PATENTS AND ORDERED TO BE PRINTED.

WAR DEPARTMENT,
April 11, 1876.

The Secretary of War has the honor to transmit to the House of Representatives, for the information of the Committee on Patents, in response to a letter of the 10th instant from Hon. Samuel A. Dobbins, chairman of Sub-committee on Patents, a letter of the 10th instant from the Chief of Ordnance on House bill 2865, transmitting also an extract from his annual report of 1875 on infringement of patents, and copy of letter of October 11, 1875, to the Secretary of War, on the same subject, with recommendation.

ALPHONSO TAFT,
Secretary of War.

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, April 10, 1876.

SIR: I have the honor to return House of Representatives bill No. 2865, "extending the jurisdiction of the Court of Claims, and for other purposes," now pending before the House Committee on Patents. I also transmit an extract from my annual report of 1875 on "infringement of patents," and copy of letter to the honorable Secretary of War, dated October 11, 1875, on the same subject.

The provisions of this bill, with the amendments, in writing, interlined and in margin, have my hearty approval, and will, it is believed, relieve the War Department from the great embarrassments which have been frequently brought to the attention of Congress in previous reports, and give a sure, speedy, and uniform method of settling the claims of patentees against the United States for the use of patents.

In the further interest of patentees and of the United States, I would respectfully recommend two additional amendments, which have been inserted in the margin in red ink, viz: page 2, line 18, after the word "provided," insert "such cases to be preferred causes in said court;" and on page 11, section 12, line 4, after the word "provided," insert "such cases, so appealed, to be preferred causes in said court." These additional amendments are necessary to avoid delay in the determination of said causes.

Respectfully, your obedient servant,

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

The Hon. the SECRETARY OF WAR.

[H. R. 2865, 44th Congress, 1st session.]

IN THE HOUSE OF REPRESENTATIVES, MARCH 27, 1876.—Read twice, referred to the Committee on Patents, and ordered to be printed.

Mr. MARTIN I. TOWNSEND, on leave, introduced the following bill:

A BILL extending the jurisdiction of the Court of Claims, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That if the Secretary of War, or of the Navy, or of the Treasury, or of the Interior Department, or the Postmaster-General, or any other officer of the United States of America, has used, or shall hereafter use, in the public service, either under or without an express or implied contract, any invention upon which the letters-patent of said United States have been issued or re-issued or extended and renewed, whereby, and by means of which, such service has been, or is, improved or benefited, either in the saving of labor, or in the reduction of expenses in the management of Government affairs, or if such service has been, is, or shall be, in any other way or manner improved or benefited, the Court of Claims of the United States is now and hereby vested with full and complete jurisdiction in and over any and all such cases, the same to be brought into and before said Court of Claims, in the manner and for the purposes herein provided; such cases to be preferred causes in said court, and whose duty shall be to hear, investigate, and determine any and all such cases submitted to said court upon pleadings and proofs in the manner herein provided for it to hear, investigate, and determine, and involving the following questions of fact for the consideration and judgment of said court, to wit:

First. The granting and issuing of the letters-patent, set forth by date and number thereof, and described in the petition or bill of complaint filed in said court in the manner substantially as hereinafter provided; and also the validity of such letters-patent, with the same jurisdiction and power that the circuit court of the United States now has over and upon such matter;

Second. The use of the improvements, invention, and letters-patent thereon in the business and service of said United States, and in what Department, and for what purpose used, and the duration of that use;

Third. The compensation or sum of money to be paid by said United States, upon the evidence submitted, for such use of the improvements, invention, and letters-patent so applied to the public service; and,

Fourth. The right, title, and ownership of the letters-patent specified in the petition or bill of complaint in the manner aforesaid; and to whom the compensation for such use of invention and letters-patent thereon shall be awarded and paid by said United States.

SEC. 2. That in each and all cases where either of the several Departments or any officer of the Government of said United States have put into use in the service of said Government of the United States any patented invention or improvements, the Cabinet officer at the head of the Department using such patented invention or improvements shall, if requested so to do by the written application of the inventor and original patentee, or his assignee or assignees, or either of them, of the invention so used, and within ten days thereafter, having been first furnished with a duly-verified copy of the petition or bill of complaint containing the facts and the grounds relied upon for recovery against said United States, in the manner herein provided, refer the same to said Court of Claims for the purposes herein named; whereupon that court

shall proceed and take full and complete jurisdiction of each and every matter contained in such verified petition or bill of complaint, in the same manner provided in section one of this act; and shall hear and determine the same, and all matters contained in the answer thereto, in the manner herein provided.

SEC. 3. That if either of the said several Departments have had, have, or shall have in use in the service and business of the United States, any improvements or invention upon which the letters-patent of said United States have been issued, the inventor and original patentee named in the letters-patent, or in any re-issue or any extension and renewal thereof, or any person or persons claiming to be the owner or owners of any interest in such letters-patent by a deed of assignment in writing, duly made and acknowledged before some officer having authority by law to take acknowledgments, and the same of record in the Patent-Office of said United States, the original deed of assignment so made and recorded, or a duly-certified copy thereof, being produced and made a part of the said petition or bill of complaint, may make the said United States defendant, and thus and thereby give the said Court of Claims the jurisdiction contained in section one of this act. The said petition or bill of complaint shall be in writing, and shall be the same, or substantially the same, as a bill in equity in the circuit court of the United States filed against an infringement of any letters-patent in that court, and shall set forth therein all the matters of fact which said Court of Claims is, by this act, required to pass upon and to determine at the final hearing of the case so referred or brought to the jurisdiction of said court, to which the Attorney-General of said United States shall make answer within thirty days next after service upon him of a duly-certified copy of the said petition or bill so made and filed with the clerk of said Court of Claims, and upon the filing of such answer with the clerk of said court, the issues shall be fully joined and the case ready for proofs, to be taken in the manner herein provided.

SEC. 4. That every such petition or bill of complaint shall be signed and sworn to by the petitioner or petitioners aforesaid before a United States commissioner, or a commissioner of said Court of Claims, or before a judge of a court of record having a seal; and the same shall also be signed by the attorney and counsel of record for the petitioner or petitioners in said Court of Claims; and in like manner the answer of the Government of said United States thereto shall be duly signed by the Attorney-General aforesaid in his official capacity. And after the filing of said answer in the manner hereinbefore stated and provided, eight days' notice, exclusive of the day of the service thereof, shall be given to said Attorney-General by said petitioner or by the petitioner's attorney of record in said Court of Claims, of the time and place for the taking of such oral and documentary proofs as are intended to be used in such cause in support of the petition or bill of complaint so made and filed in said court, after which the said Attorney-General shall, in like manner, give notice of the time and place, and shall proceed to take such proofs as he may deem necessary in support of the answer so made and filed by him in the office of the clerk of said court. The proofs or evidence named, as aforesaid, may be taken by and before a United States commissioner or a commissioner of said Court of Claims, or an examiner in equity in the United States circuit court, in the usual manner, and under the same rules as now practiced in patent causes in the said circuit court. After the direct and rebuttal proofs upon each side in any such cause have been taken and filed in the office of the clerk of said Court of Claims, such cause shall be deemed to be ready for argu-

ment and final hearing, and thereupon the same shall be put upon the current calendar or trial-docket of said court for such hearing and argument upon the evidence so taken and submitted by both the parties named in the petition or bill of complaint, or by either party thereto upon the default of the other or refusal to take proofs as herein provided; and the same shall then be proceeded with by that court to final judgment and decree in the usual manner established by said court with reference to the making and entering of final decrees and judgments.

SEC. 5. That the said Court of Claims shall fix upon and decree the rate of compensation, and the sum or amount of money to which the aforesaid inventor and original patentee, or his heirs, or assigns, or legal representative may, upon the proofs, be entitled to have and to receive in the manner claimed in and by such petition or bill of complaint so made and filed in said court, and up to the time of adjudication by said Court of Claims; all of which shall be heard and determined upon the evidence taken and submitted to said court in the manner substantially as hereinbefore provided.

SEC. 6. That any three of the judges of said Court of Claims may, upon the written application of either party named as aforesaid, regulate, by an order in writing, duly signed by them, the time, place, and the manner for the taking of proofs or evidence to be used upon either or both sides in any cause brought within this act into said court in the manner aforesaid, so as to prevent unnecessary expense or delay by either party aforesaid; but due notice thereof shall first be given to the adverse party, and said application may be heard in open court, or at the chambers of the chief-justice of said court; and in like manner upon the written application of either party, such judges may determine upon the time for the trial or final hearing and argument of any such cause so brought into said court.

SEC. 7. That if any person or persons claiming to own the whole or a part interest of the right and title to the invention and letters-patent thereon, by a good and valid deed of an assignment, made, executed, and of record in the manner hereinbefore made and provided, if there be any, who are not joined in such petition or bill aforesaid, shall be made party defendants therein with the said United States and brought into said Court of Claims, or required therein to appear, upon such notice or order as the said court shall determine and direct; and thereupon the said Court of Claims shall have the same jurisdiction of each and every matter thereof as it has herein and hereby with reference to said inventor and original patentee, and shall hear and determine the same in the manner and with the same force and effect as hereinbefore provided.

SEC. 8. That if in any cause made and filed in the said Court of Claims, in the manner as provided for by this act, anybody shall have a good, sufficient, and valid deed of assignment and transfer of the invention and letters-patent named in the petition or bill of complaint aforesaid, or of any part thereof, and if the same be of record in the United States Patent-Office as by law required, the same if required, or a duly-certified copy thereof, shall be produced in evidence in said Court of Claims by the person or persons holding and owning it, for the inspection and opinion and judgment of said court thereon; and thereupon the said court shall have full jurisdiction of the same and of all matters appertaining thereto, and may, upon evidence duly taken as hereinbefore provided, proceed to hear such cause, and to determine each and every matter that may be at issue or involved in or by the evidence so taken

and presented concerning such deed of assignment, and to whom any judgment that may be rendered, decreed, or ordered to be entered against said United States shall be paid; and in case an appeal be taken in the manner provided for in and by section twelve of this act, to the Supreme Court of the said United States, then that court may, in like manner, determine such matter and to whom the said United States shall pay any judgment so made, decreed, and entered by said Court of Claims. But if no such deed of assignment or a duly-certified copy thereof be offered and received in evidence in such cause before the closing of the direct or redirect evidence upon either side therein, then such cause shall be proceeded with, and heard and determined by said court in the manner hereinbefore made and provided. Any person who may have any knowledge or evidence concerning the matters involved in the petition or bill aforesaid, or in the answer thereto, may be examined as a witness, by and in behalf of the parties to such suit, or either of them.

SEC. 9. That any proofs or evidence taken in pursuance of the provisions contained in this act shall be duly certified to by the officer before whom and by whom the same is taken, and thereupon the same shall be securely sealed up by such officer, and by him transmitted to the clerk of said Court of Claims, in the same manner as now practiced in the said circuit court of the United States, or as required by the rules of practice in said Court of Claims, which shall be done within thirty days next after the taking of the same as aforesaid is completed. Duly-certified copies of any record papers, other than that of deeds of assignment, or transfers, or licenses, may be used in evidence in any such cause in said court in the same manner and with the same effect as other evidence is used in or by said Court of Claims.

SEC. 10. That if such letters-patent have been renewed or extended by the Commissioner of Patents or by an act of Congress, or if the same have been re-issued either before or after any renewal or extension thereof, the jurisdiction of said Court of Claims, conferred by this act, shall apply to the same; and the right of recovery against said United States as herein provided for the use of the invention so patented, or re-issued, or renewed and extended, shall be under either the original letters-patent or any re-issue thereof, or under any renewed and extended term of the same; and the same, and each and every thereof, may be included in the same petition or bill of complaint, and the compensation for the use of the invention so patented shall be fixed and determined upon the length of time the same has been used in the public service by the direction of either of the Departments, or any officer named in section one of this act.

SEC. 11. That in case of the decease of said inventor and original patentee, or of any such assignee, either before or after the filing of any such petition or bill of complaint as aforesaid, then his administrator or executor, or administratrix or executrix, for the benefit of the heirs and estate of such deceased inventor and patentee, or of such assignee, shall be deemed, and shall be, the rightful and lawful party against said United States for all and every of the purposes mentioned and provided for in this act, and may prosecute the same to final judgment and decree in either or both of said courts; and shall be responsible and accountable to such estate therefor, in the same manner as provided by law in the State where such estate shall be situated at the time of the decease of such inventor and patentee, or assignee.

SEC. 12. That either party aforesaid may appeal to the Supreme Court of said United States within thirty days next after judgment or

final decree shall have been made and ordered by said Court of Claims as hereinbefore provided; such cases, so appealed, to be preferred causes in said court; and if the said judgment or final decree shall not be appealed, or, if appealed, and the said judgment or final decree shall be affirmed by said Supreme Court, then the same shall be certified by the said Court of Claims to the Secretary of the Treasury of said United States in the same manner as now provided by the law in relation to any other judgment of said Court of Claims; and the same, when presented to the Secretary of the Treasury aforesaid, shall have the same effect as now provided by law, and shall thereupon be paid out of any general appropriation in relation to judgments of said Court of Claims or for private claims; and the payment of such judgment shall be in full satisfaction for all claims for compensation for the use of such patented invention or improvements up to the time of the making and entering of such judgment or decree thereon by the said court, and no longer; or such judgment may be paid by the Secretary of the Treasury of said United States out of any money in the said Treasury not otherwise appropriated, with the same effect as though the same had been paid out of any money appropriated for the payment of judgments of said Court of Claims or for private claims.

SEC. 13. That this act shall take effect immediately after its passage and approval.

EXTRACT FROM ANNUAL REPORT OF CHIEF OF ORDNANCE FOR 1875 ON INFRINGEMENT OF PATENTS.

I have the honor again to advert to the subject of patent-claims set up against this Department for alleged infringements in the productions at the National Armory, and at the several arsenals of construction. The Chief of Ordnance, in his report for the year 1873, gave a succinct statement of the state of those claims at that time. The claims on the Springfield rifle date back to the order of the Secretary of War of July 28, 1866, for the conversion of 50,000 muzzle-loaders to breech-loading arms. The skill and ingenuity of the officers and workmen of the Ordnance Department, brought into active operation previous to that time and continued to the present, have resulted in the production of as perfect a single breech-loading arm as will find its place in modern war. Its mechanism, it is claimed, has touched upon and appropriated in part the best features of several distinct and separate patents, some of which were perfected and re-issued after the work of the Government had begun, and whose owners are now seeking compensation for the use.

The consideration, of a patent-case involves a careful weighing of many matters of fact relating to novelty, priority, &c., as well as an appreciation of equivalents and dissimilarities in mechanical structures and contrivances, and the proper application of the principles of patent-law to facts thus found. Where a device stands boldly out as the original type of its class, and the many questions of a character to affect the validity of the patent are in such a case reasonably free from doubt, it is apprehended that it would require but ordinary patent-expert skill to settle with certainty the merits of any question of infringement that might be raised; but where *several* claimants profess to cover by their patents the same identical device or combination, a proper regard to the several interests involved renders the matter more difficult of determination. An impartial settlement requires, in most cases, the assistance of the highest degree of expert skill and the exercise of the highest

order of legal talent in the specialty of patent-law. The law prescribes a judicial method of settlement where private parties only are concerned, but the means of deciding properly between contending patentees and determining the amount of damages sustained by them, or any of them, where the Army workshops are concerned, are not vested in any portion of this Department, nor, indeed, as respects cases wherein the United States are properly the defendants, are they known to be vested in any Department of the Government at the present time.

The methods adopted by some of the claimants of instituting suits in the United States circuit courts against officers of this Department for the alleged infringements is onerous to the officers themselves, and can only result, in the event of the success of the suits, in embarrassing such officers in their private means, whereas the Government is the sole beneficiary in the use of the things which are the subject-matters of litigation. A recent opinion of the Attorney-General has inferentially decided that the executive officers of the Government are not authorized to settle the judgments, for past use, rendered in such suits, without authority of Congress to do so. This opinion has been the guide of this bureau since that time. The officers, therefore, against whom judgments might be rendered would be put to the harassing necessity of securing special legislation for their relief in respect to matters over which they have had little or no power or control.

The indemnity due to public officers who have acted in pursuance of competent authority in the performance of their public duty, or who have in good faith exercised the discretion vested in them by law, is secured to a certain class of Government officials by general legislation. Collectors and other officers of the revenue are thus secured by section 989, Revised Statutes. It is therein enacted, that when a recovery is had in any suit or proceeding against such officer for any act done by him in the performance of his official duty, and the court certifies that there was probable cause for the act done by him, or that he acted under the direction of the Secretary of his Department, or other proper officer of the Government, no execution shall issue against him, but the amount so recovered shall, upon final judgment, be provided for and paid out of the proper appropriation from the Treasury. *Legislation similar to the foregoing, in favor of the officers of this Department* against whom recoveries may be had for infringement of patents in the productions of the Armory and arsenals, would be a practicable method of relieving this bureau of a present embarrassment.

It is believed, however, that, where several patents are alleged to cover a single complex device, each of these patents should be brought under the adjudication of a *common* tribunal, where the combined wisdom and experience necessary to the disposal of the whole number of cases could be brought to bear on each particular one in detail. If suits on such a device are brought by the several patentees in widely-separated jurisdictions, there is great liability of undue compensation being awarded to one patentee and inadequate remuneration to another, when the relative importance of the several patents is thereafter taken into account. It is, therefore, a question in the interest of the patentees themselves, as well as of public economy, whether some particular forum should not be named wherein claims of the character here referred to should be exclusively brought. The Court of Claims has denied its jurisdiction in cases of infringement of patent-rights by the Government, because such claims are held to sound in *tort*, and because the jurisdiction of the circuit courts is by law made exclusive in cases of patents. (See Pitcher's case, and Nock's case, 1 C. C. Repts., pp. 7 and 83.) Were it not, therefore, for

these limitations upon the jurisdiction of the Court of Claims, this Department might readily refer all cases of alleged infringement for the decision of that tribunal under section 1063 of the Revised Statutes. Claimants before this bureau for past use are now, however, without a remedy, except by personal actions against the officers of the Ordnance Department, (who have been and are acting under superior authority,) or by a direct application to Congress. As indicating the direction heretofore given by Congress to a complicated patent-case arising out of this bureau, in order to secure for it the careful legal investigation which its importance demanded, attention is respectfully invited to the joint resolution of June 3, 1864, (13 S. L., p. 588,) referring the claim of William W. Hubbell to the Court of Claims. This claim was founded upon the use by the Government, to a very large extent, of devices covered by the patents of the claimant; and the court was directed to investigate and determine whether the claimant was the original inventor of the particular devices in question, and if he had a just and equitable right to compensation for the same; if so, what amount of compensation he was entitled to receive for the use of the inventions up to the time of adjudication, and for a full and entire transfer of his patents to the United States. This case, therefore, furnishes a precedent for the method of settling this class of cases; and, coupled with the advantages to accrue from the adjudication in a single tribunal of all patents where the United States is defendant, I would respectfully submit it to the wisdom of Congress *whether jurisdiction ought not to be given to the Court of Claims in all cases of the character here explained where the United States is defendant.* I earnestly recommend that some action may be taken at the coming session on this subject, which has engaged the attention of this bureau for so long a time.

LETTER OF CHIEF OF ORDNANCE RELATING TO THE INFRINGEMENT OF PATENTS.

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, October 11, 1875.

SIR: I have the honor to submit the propriety of soliciting from the Attorney-General his concurrence in an effort which I request may be made to secure from Congress the passage of an act authorizing this Department, whenever the public interest may demand it, to prosecute in the National Armory and the arsenals of construction the manufacture of articles of ordnance destined for public use in the military service, without regard to any patent-rights granted by the Government, and prescribing a judicial method of awarding compensation from the Treasury to holders of patents, upon their making it to appear in a proper tribunal that their letters-patent, being valid, are the subject of infringement by this Department, and showing the amount of compensation to which they are reasonably entitled.

The reasons which prompt me to make this request are the following:

Upon directions being given by the Secretary of War to this bureau, any article of ordnance whatever must, by the rules of the military service, be purchased or manufactured in the public workshops of the Armory and arsenals, if the appropriations for this branch of the service will permit the expenditure. Where machinery adequate to the production of articles ordered is not on hand, it also has to be purchased or manufactured as above.

It is out of these manufactures by the United States that much diffi-

culty has arisen to this bureau during the past few years; difficulties resulting from actual or supposed infringement of patent-rights held by private inventors, or by persons or corporations who have become the assignees of such rights.

Without attempting to enumerate all the instances that have occurred or may occur in this Department, it may be stated generally that few departures from known devices can be made in the Government workshops without originating a demand against the Department for allowance of royalty for infringement of letters-patent. The class of war materials, like all other classes, is open to all the world for improvement; a not inconsiderable portion of the world avails itself of the opportunity, and this whole field of invention is overlaid with the paper-grants of the Government under the laws for promoting the progress of science and the useful arts.

Did a patent granted by the Government convey *per se* an incontestable right to remuneration for any invasion of the same, one element of difficulty would be obviated in the consideration of questions relating to infringement; but as the granting of a patent or a re-issue by the Patent-Office is a mere ministerial act, not professing to be a warranty of the franchise conferred, the recognition of such act as conclusive in any given case must be made in the face of all the possible infirmities which may inhere in it. That radical and fatal infirmities do exist in numbers of cases the records of adjudications of patent cases in the courts will amply attest. Where, therefore, controversies are raised between owners of patents in which this Department may be considered as an infringer, it is manifestly not in the province of the Department to settle contending rights, as the judicial machinery necessary to that end is nowhere vested in it. Meanwhile, however, the Department continues the manufacture or use, without the power to decide whose claim before it is the most meritorious.

Nor is there any plain, adequate remedy provided by law whereby claimants can obtain remuneration from the Government. The infringement of a patent has been held to partake of the nature of a *tort* on the part of the individual infringer; it has been so held by the Court of Claims in Pitcher's case and Nock's case, (1 C. C. Repts., pp. 7 and 83,) and in the case of Ely *vs.* Benton, which was before the United States circuit court for the district of Massachusetts in 1871. The question whether or not the commanding officer of the National Armory was personally answerable in damages to the owner of a patent infringed in the manufactures under his direction at the armory was reserved on division for the decision of the United States Supreme Court. The question was never pressed before the Supreme Court, and may therefore be considered as yet an open one. *It is for the settlement of this question, as well as for providing a method of remuneration from the Treasury to meritorious patentees, that legislation is now asked.* The United States is the real beneficiary of the acts of its agents at the armory and arsenals, who can only act in obedience to the superior authority of the War Department.

Where manufactures or use by the United States have continued for any length of time without the consent of the holder of a patent, it has been held by the Attorney-General that no award of public moneys as damages can be made to such holder of patent without authority of Congress; the infringement being in the nature of a damage, which an executive officer is not authorized to adjudicate upon.

Were there no other difficulties to be encountered in the settlement of these patent cases, the single question of "measure of damages" would take each case out of the jurisdiction of this Department.

As before suggested, there is no judicial process under the control of this Department by means of which the proper damages to be allowed may be estimated or determined. Between private parties actions for infringement may be either at law or in equity. At law, "actual" damages alone are allowed, and these are to be found through the instrumentality of *a jury*, and are subject to be trebled by the judge at his discretion in favor of the party whose right is infringed. And it has been held (16 How., 480,) that "actual damages must be actually proved, and cannot be assumed as a legal inference from any facts which amount not to actual proof of the facts." In equity, besides the profits that may have accrued to the infringer, the complainant is entitled to recover the damages he has sustained, subject to being trebled, as at law, and the court is authorized to assess the damages or cause the same to be assessed. From the judgment or decrees in either form of action appeals are provided in the ordinary course of judicial procedure. A simple glance at these methods of settlement of cases of infringement between individuals, therefore, will show the inability of an executive officer (who is not invested with judicial functions, and from whose judgment no judicial appeal in such cases is provided) to settle patent cases wherein the United States is concerned.

In the absence of any better method of disposing of the cases which have accrued in this bureau, it has been the custom to refer them to the Department of Justice, with the request that an opinion might be expressed upon the validity of the patents, and that a method of settlement might be suggested. In one instance, the papers, after an opinion had been furnished by the Department of Justice, were referred to an officer of ordnance, familiar with the subject-matter of the patents, for an opinion upon the amount of damages. Some of the cases are still pending in the Department of Justice.

Upon recent reflection I have arrived at the conclusion that the method adopted in these cases is not the best for subserving the individual interests of the claimants and of the Government, and the Department is powerless to afford relief in any case without the action of Congress. As this power has, in any event, to be invoked, I would recommend that general legislation be asked so as to cover all the cases. This can best be done by designating some special tribunal wherein actions may be brought against the Government for alleged infringement in the workshops and in the products of the Ordnance Department. My views in this regard are embraced in the inclosed extract from my annual report of this year, and the measure therein suggested is the one which I would earnestly ask may be submitted to the Attorney-General for his influence and support, if it should commend itself to his judgment.

I have the honor to be, very respectfully, your obedient servant,

S. V. BENÉT,
Brig. Gen., Chief of Ordnance.

The Hon. SECRETARY OF WAR.

S. 571.—Forty-fourth Congress, first session.

[Report No. 467.]

In the Senate of the United States, July 15, 1876.—Ordered to be printed.

Amendment reported by Mr. Wadleigh, from the Committee on Patents, to the bill (S. 571) extending the jurisdiction of the Court of Claims of the United States, and for other purposes, viz: Strike out all after the enacting clause and insert the following:

That if the Secretary of War, or of the Navy, or of the Treasury, or of the Interior Department, or the Postmaster-General, or any other offi-

cer of the United States, acting under authority from the head of any Executive Department, or of any bureau of the said several Departments of the Government of said United States, has used, or shall hereafter use, in the public service, any invention upon which the letters-patent of said United States have been issued, or re-issued, or extended and renewed, whereby, and by means of which, such service has been, or is, improved or benefited, either in the saving of labor or in the reduction of expenses in the management of Government affairs, or if such service has been, is, or shall be in any other way or manner improved or benefited, the Court of Claims of the United States is now and hereby vested with full and exclusive jurisdiction in and over any and all such cases, the same to be brought into and before said Court of Claims, by a petition or bill of complaint verified and filed in said court, in the manner and for the purposes herein provided, and whose duty shall be to hear, investigate, and determine any and all such cases submitted to said court, upon pleadings and proofs, in the manner herein provided for it to hear, investigate, and determine, and involving the following questions of fact for the consideration and judgment of said court, to wit:

First. The granting and issuing of the letters-patent, or of any re-issue or extension and renewal thereof, each of which shall be set forth by date and number, and described in the petition or bill of complaint filed in said court in the manner substantially as hereinafter provided; and also the validity or the invalidity of such letters-patent, or of any re-issue or extension and renewal thereof, with the same jurisdiction and power that the circuit court of the United States now has over and upon such matter or such questions of fact;

Second. The use of the improvements, invention, and letters-patent thereon in the business and service of said United States, and in what Department, and for what purpose used, and the extent of that use within the life-time or duration of the grant of the letters-patent upon which such petition or bill of complaint is founded, as herein required and provided;

Third. The compensation or sum of money to be paid by said United States, upon the evidence submitted, for such use of the improvements, invention, and letters-patent so applied to the public service; and,

Fourth. The right, title, and ownership of the letters-patent specified in the petition or bill of complaint in the manner aforesaid; and to whom the compensation for such use of invention and letters-patent thereon shall be awarded and paid by said United States.

SEC. 2. That if either of the said several Departments have had, have, or shall have in use in the service and business of the United States, any improvements or invention upon which the letters-patent of said United States have been issued, the inventor and original patentee named in the letters-patent, or in any re-issue or any extension and renewal thereof, or any person or persons claiming to be the owner or owners of any interest in such letters-patent by a deed of assignment in writing, duly made and acknowledged before some officer having authority by law to take acknowledgments, and the same of record in the Patent-Office of said United States, the original deed of assignment so made and recorded, or a duly-certified copy thereof, being produced and made a part of the said petition or bill of complaint, may make the said United States defendant, and thus and thereby give the said Court of Claims the jurisdiction contained in section one of this act, upon the filing of a duly-verified petition or bill of complaint, as herein provided, in said court, and serving the Attorney-General with a duly-certified copy of the same so filed by the petitioner or complainant.

The said petition or bill of complaint shall be in writing, and shall be the same, or substantially the same, as a bill in equity in the circuit court of the United States filed against an infringement of any letters-patent in that court, and shall set forth therein all the matters of fact which said Court of Claims is, by this act, required to pass upon and to determine at the final hearing of the case so referred or brought to the jurisdiction of said court, to which the Attorney-General of said United States shall plead or make answer within thirty days, or such time as said court may fix upon, next after service upon him of a duly-certified copy of the said petition or bill so made and filed in the said Court of Claims; and upon the filing of such plea or answer in said court, the issues shall be fully joined and the case ready for proofs, to be taken in the manner herein provided. And among other defenses which the said Attorney-General may make for and on the part and behalf of said United States, by plea or answer to such petition or bill of complaint, he may make the following special defenses, to wit:

In any action for infringement, the defendant may plead the general issue, and having given notice in writing to the plaintiff or his attorney thirty days before, may prove, on trial, any one or more of the following special matters:

First. That for the purpose of deceiving the public the description and specification filed by the patentee in the Patent-Office was made to contain less than the whole truth relative to his invention or discovery, or more than is necessary to produce the desired effect; or,

Second. That he had surreptitiously or unjustly obtained the patent for that which was in fact invented by another, who was using reasonable diligence in adapting and perfecting the same; or,

Third. That it had been patented or described in some printed publication prior to his supposed invention or discovery thereof; or,

Fourth. That he was not the original and first inventor or discoverer of any material and substantial part of the thing patented; or,

Fifth. That it had been in public use or on sale in this country for more than two years before his application for a patent, or had been abandoned to the public.

And the said United States may plead the same defenses in any action brought under this act as are allowed to be pleaded by any defendant in any action or in any suit for infringement in the United States circuit court under existing laws: *And it is hereby provided*, That in case where the validity of a patent has been sustained or overthrown in the circuit court of the United States, in an action at law, or in a suit in equity, between private parties, the transcript of the proceedings thereof in such court, being duly certified, and put in evidence upon due notice to the adverse party, shall have the same weight and force in said Court of Claims as the decisions of one court now have in another of similar jurisdiction.

SEC. 3. That every such petition or bill of complaint shall be signed and sworn to by the petitioner or complainant aforesaid before a United States commissioner, or a commissioner of said Court of Claims, or before a judge of a court of record having a seal; and the same shall also be signed by the attorney and counsel of record for the petitioner or complainant in said Court of Claims; and, in like manner, the plea or answer of the Government of said United States thereto shall be duly signed by the Attorney-General aforesaid in his official capacity. And after the filing of said plea or answer in the manner hereinbefore stated and provided, fifteen days' notice, exclusive of the day of the service thereof, shall be given to said Attorney-General, by said petitioner or by the petitioner's attorney of

record in said Court of Claims, of the time and place for the taking of such oral and documentary proofs as are intended to be used in such cause in support of the petition or bill of complaint so made and filed in said court, after which the said Attorney-General shall, in like manner, give notice of the time and place, and shall proceed to take such proofs as he may deem necessary in support of the plea or answer so made and filed by him in the office of the clerk of said court. The proofs or evidence named as aforesaid may be taken by and before a United States commissioner, or a commissioner of said Court of Claims, or an examiner in equity in the United States circuit court, in the usual manner, and under the same rules as now practiced in patent causes in the said circuit court. After the direct and rebuttal proofs upon each side in any such cause have been taken and filed in the office of the clerk of said Court of Claims, such cause shall be deemed to be ready for argument and final hearing; and thereupon the same shall be put upon the current calendar or trial-docket of said court for such hearing and argument upon the evidence so taken and submitted by both the parties named in the petition or bill of complaint, or by either party thereto, upon the default of the other, or refusal to take proofs as herein provided; and the same shall then be proceeded with by that court to final judgment and decree in the usual manner established by said court with reference to the making and entering of final decrees and judgments.

SEC. 4. That the said Court of Claims shall fix upon and decree the rate of compensation, and the sum or amount of money to which the aforesaid inventor and original patentee, or his heirs or assigns, or legal representative, may, upon the proofs, be entitled to have and to receive in the manner claimed in and by such petition or bill of complaint so made and filed in said court, and up to the time of adjudication by said Court of Claims; all of which shall be heard and determined upon the evidence taken and submitted to said court in the manner substantially as hereinbefore stated: *Provided*, That the rate of compensation and the sum awarded by the court shall, in all cases admitting of such computation, be computed upon the basis of a reasonable royalty due for the use of the claimant's right; and in no case shall the sum so awarded exceed the profit or benefit derived by the United States from the use of such right.

SEC. 5. That any one of the judges of said Court of Claims may, upon the written application of either party named as aforesaid, regulate, by an order in writing, duly signed by him, the time, place, and the manner for the taking of proofs or evidence to be used upon either or both sides in any cause brought within this act into said court in the manner aforesaid, so as to prevent unnecessary expense or delay by either party aforesaid; but due notice thereof shall first be given to the adverse party, and said application may be heard in open court, or at the chambers of the judge before whom said application is made; and in like manner, upon the written application of either party, said court may determine upon the time for the trial or final hearing and argument of any such cause so brought into said court.

SEC. 6. That any person or persons claiming to own the whole or a part interest of the right and title to the invention and letters-patent thereon, by a good and valid deed of an assignment, made, executed, and of record in the manner hereinbefore made and provided, or otherwise claiming any interest therein, who are not joined in such petition or bill aforesaid, may be made party defendants therein with the said United States, and brought into said Court of Claims, or required therein to appear upon such notice or order as the said court shall de-

termine and direct; and thereupon the said Court of Claims shall have the same jurisdiction of each and every matter thereof as it has herein and hereby with reference to said inventor and original patentee, and shall hear and determine the same in the manner and with the same force and effect as hereinbefore provided.

SEC. 7. That if in any cause made and filed in the said Court of Claims, in the manner as provided for by this act, anybody shall have a good, sufficient, and valid deed of assignment and transfer of the invention and letters-patent named in the petition or bill of complaint aforesaid, or of any part thereof, and if the same be of record in the United States Patent-Office, as by law required, the same, if required, or a duly-certified copy thereof, shall be produced in evidence in said Court of Claims, by the person or persons holding and owning it, for the inspection and opinion and judgment of said court thereon; and thereupon the said court shall have full jurisdiction of the same, and of all matters appertaining thereto, and may, upon evidence duly taken, as hereinbefore provided, proceed to hear such cause, and to determine each and every matter that may be at issue or involved in or by the evidence so taken and presented concerning such deed of assignment, and to whom any judgment that may be rendered, decreed, or ordered to be entered against said United States shall be paid; and in case an appeal be taken in the manner provided for in and by section twelve of this act, to the Supreme Court of the said United States, then that court may, in like manner, determine such matter, and to whom the said United States shall pay any judgment so made, decreed, and entered by said Court of Claims. But if no such deed of assignment, or a duly-certified copy thereof, be offered and received in evidence in such cause before the closing of the direct or redirect evidence upon either side therein, then such cause shall be proceeded with, and heard and determined, by said court in the manner hereinbefore made and provided. Any person who may have any knowledge or evidence concerning the matters involved in the petition or bill aforesaid, or in the plea or answer thereto, or any part thereof, may be examined as a witness by and in behalf of the parties to such suit, or either of them. And any and all persons now allowed to testify as a witness in patent or other causes in the circuit court of the United States shall be competent to testify and render evidence in said Court of Claims in any suit brought under this act, and in behalf of either party thereto.

SEC. 8. That any proofs or evidence taken in pursuance of the provisions contained in this act shall be duly certified to by the officer before whom and by whom the same is taken; and thereupon the same shall be securely sealed up by such officer, and by him transmitted to the clerk of said Court of Claims, in the same manner as now practiced in the said circuit court of the United States, or as required by the rules of practice in said Court of Claims, which shall be done within twenty days next after the taking of the same as aforesaid is completed. Duly-certified copies of any court or other record-papers, other than that of deeds of assignment, or transfers, or licenses, may be used in evidence in any such cause in said court in the same manner and with the same effect as any other evidence is used in or by said Court of Claims, or by the circuit court of said United States.

SEC. 9. That if such letters-patent have been renewed or extended by the Commissioner of Patents or by an act of Congress, or if the same have been re-issued either before or after any renewal or extension thereof, the jurisdiction of said Court of Claims, conferred by this act, shall apply to the same; and the right of recovery against said United

States as herein provided for the use of the invention so patented, or re-issued, or renewed and extended, may be under either the original letters-patent or any re-issue thereof, or under any renewed and extended term of the same; and the same, and each and every thereof, may be included in the same petition or bill of complaint, and the compensation for the use of the invention so patented shall be fixed and determined upon the length of time the same has been used in the public service by the direction of either of the Departments, or any officer named in section one of this act: *Provided*, That the invention or improvement so patented shall have been used in the public service, in the manner hereinbefore stated, under either the original, or re-issued, or extended and renewed letters-patent.

SEC. 10. That in case of the decease of said inventor and original patentee, or of any such assignee, either before or after the filing of any such petition or bill of complaint as aforesaid, then his administrator or executor, or administratrix or executrix, for the benefit of the heirs and estate of such deceased inventor and patentee, or of such assignee, shall be deemed, and shall be, the rightful and lawful party against said United States for all and every of the purposes mentioned and provided for in this act, and may prosecute the same to final judgment and decree in either or both of said courts, and shall be responsible and accountable to such estate therefor, in the same manner as provided by law in the State where such estate shall be situated at the time of the decease of such inventor and patentee or assignee.

SEC. 11. That hereafter the district or circuit courts of said United States shall not have or take jurisdiction over or against any officer or person in the service or employment of the Government of said United States who uses, or may have used, in the public service, for said Government, any improvement or invention, and letters-patent thereon, in the manner stated in section one of this act; but sole and exclusive jurisdiction over and upon any and every such act of infringement is hereby conferred upon, and vested in, the said Court of Claims, with the same privileges, rights, and powers as now given by law to said district or circuit courts over and upon any letters-patent upon inventions, and all questions of validity or invalidity, infringements, title, or any other matter or question appertaining to any such letters-patent. And this act shall be construed so as to give authority or license to said United States to make for, and to use in, such public service any patented invention, upon the condition, and only the condition, that the patentee, or assignee, or claimant of ownership of such letters-patent, or their legal representatives, shall go to the said Court of Claims in the manner and form provided in this act, for the adjudication, settlement of, and payment for, such infringement of the letters-patent or use of the invention therein and thereby patented.

SEC. 12. That each and every claim cognizable by the said court under this act shall be forever barred unless the petition or bill of complaint setting forth a statement of the case and claim, as herein required, be filed in said court within three years after the cause of action first accrued: *Provided*, That any such claim which has accrued prior to the passage of this act shall not be barred if the petition or bill of complaint be filed in said court within two years after the passage of this act, and not more than six years after the expiration of the term of years for which the letters-patent were granted, or re-issued, or extended and renewed.

SEC. 13. That either party aforesaid may appeal to the Supreme Court of said United States within ninety days next after judgment or

final decree shall have been made and ordered by said Court of Claims as hereinbefore provided, such cases so appealed to be preferred causes in said court; and if the said judgment or final decree shall not be appealed, or, if appealed, and the said judgment or final decree shall be affirmed by said Supreme Court, then the same shall be certified by the said Court of Claims to the Secretary of the Treasury of the United States in the same manner as now provided by the law in relation to any other judgment of said Court of Claims; and the same, when presented to the Secretary of the Treasury aforesaid, shall have the same effect as now provided by law, and shall thereupon be paid out of the appropriations which shall annually be made for the payment of the judgments of said court rendered under the provisions of this act; and the payment of such judgment shall be in full satisfaction for all claims for compensation for the use of such patented invention or improvements up to the time of the making and entering of such judgment or decree thereon by said court, and no longer.

Senate Report No. 467, Forty-fourth Congress, first session.

In the Senate of the United States, July 15, 1876.—Ordered to be printed.

Mr. Wadleigh submitted the following report, (to accompany bill S. 571:)

The Committee on Patents, to whom was referred the bill (S. 571) extending the jurisdiction of the Court of Claims of the United States, and for other purposes, report:

Your committee have duly considered the same, and after a careful and thorough examination of the whole subject-matter contained therein, have come to the conclusion and determination that the same has merit, and strongly invites and demands the most favorable consideration and action of the Congress of the United States. Your committee, therefore, recommend the passage of the accompanying bill as a substitute for Senate bill No. 571, first above mentioned.

The examination by your committee into the several matters contained in the bill discloses the fact that it is an important public measure, whereby the Government and the citizen are alike protected, upon common grounds in equity, as well as before the organic law of the land, by which the several Departments of the Government will now and hereafter be greatly relieved from that class of burdensome, vexatious, and expensive litigation so fully and clearly specified in the annual report of the Chief of Ordnance to the Secretary of War for the fiscal year ending June 30, 1875, on pages 11, 12, and 13 thereof, under the title of "Infringement of patents," which was fully confirmed and approved by the Secretary of War in his report to Congress on the operations of the War Department for the fiscal year ending June 30, 1875, and found on pages 19 and 20 of volume 1 of that report, to each of which your committee most respectfully request the attention and consideration of the Senate, and which your committee make a part of their report.

In order that your committee might be in possession of the facts upon which this bill appeared to be founded, so as to give to the Senate as full and correct information as possible to be had concerning the matters contained therein; and inasmuch as the Secretary of War had, in his annual report to the President, dated November 22, 1875, made mention of the same subject-matter contained in the bill, among other things,

saying: "It is, therefore, a question in the interest of the patentees themselves as well as of public economy, whether some particular form should not be named wherein claims of the character here referred to should be *exclusively* brought. I would respectfully submit it to the wisdom of Congress whether jurisdiction ought not to be given to the Court of Claims in all cases of the character here explained when the United States is defendant. I earnestly recommend that some action may be taken at the coming session on this subject;" and the same having been approved by the President, and by him transmitted to Congress in his last annual message. Senate bill No. 571 was transmitted to the Secretary of War, and by him was referred to the Chief of Ordnance on the 13th day of March, 1876, for him to examine and report thereon.

On the 16th day of March, 1876, the Chief of Ordnance, General Benét, made a report in writing to the Secretary of War, which is in the following words, to wit:

"SIR: I have the honor to return Senate bill No. 571, 'extending the jurisdiction of the Court of Claims of the United States, and for other purposes,' now pending before the Senate Committee on Patents.

"I also transmit an extract from my annual report of 1875, on 'infringement of patents,' and copy of a letter addressed to the honorable Secretary of War, October 11, 1875, on the same subject.

"The provisions of this bill meet my hearty approval, believing that they will relieve the War Department from great embarrassments which have been frequently brought to the attention of Congress in previous reports, and give a sure, speedy, and uniform method of settling the claims of patentees against the United States for the use of patents.

"If the views expressed in the inclosures meet with the concurrence of the honorable Secretary of War, it is respectfully recommended that favorable action on the inclosed bill be asked of Congress."

On the 22d day of March, 1876, the Secretary of War transmitted the said report of the Chief of Ordnance, together with other papers on the same matter, to the chairman of the Senate Committee on Patents, which was in the following words and figures, to wit:

"SIR: I have the honor to invite your attention to the inclosed letter from the Chief of Ordnance, dated the 11th instant, and accompanying papers, in regard to Senate bill No. 571, 'extending the jurisdiction of the Court of Claims of the United States, and for other purposes.'

"The letter of the Chief of Ordnance of October 11, 1875, (copy inclosed,) was transmitted to the Attorney-General on the 16th October, by the Secretary of War, requesting his views, (copy of letter inclosed,) and a copy of the reply of the Attorney-General, dated the 19th of October, is herewith inclosed.

"Action with reference to this matter was earnestly recommended by the Secretary of War in his annual report for 1875. (See pages 19 and 20 of inclosed pamphlet copy.)

"Concurring in views of the Chief of Ordnance, I have respectfully to recommend favorable action on the bill in question."

Your committee most respectfully request the attention of the Senate to the letter of the Chief of Ordnance to the Secretary of War, dated the 11th day of October, 1875; also, the letter of the Secretary of War to the Attorney-General, dated October 16, 1875, on the same subject; also, the reply of the Attorney-General thereto, dated the 19th day of October, 1875. The said letter from the Secretary of War is as follows, to wit:

"SIR: I have the honor to transmit for your views the inclosed letter

from the Chief of Ordnance, dated the 11th instant, suggesting the propriety of an effort to secure from Congress necessary legislation under which proper compensation may be awarded to holders of patents used by the United States in the manufacture of war material.

"I beg to inquire your views as to the expediency of uniting with this Department in recommending the subject to the favorable consideration of Congress at the ensuing session.

"The Hon. ATTORNEY-GENERAL."

To which the Attorney-General, under date of October 19, 1875, made the following answer, to wit:

"SIR: I have the honor to acknowledge the receipt of your letter of the 16th instant, inclosing a communication addressed to you on the 11th instant by General S. V. Benét, Chief of Ordnance, together with an extract from his annual report for this year.

"The subject suggested by these communications is, that of the propriety of an effort to secure from Congress necessary legislation by which compensation may be awarded to holders of patents used by the United States in the manufacture of war material. I concur fully with the views of General Benét concerning the necessity of such legislation, and will consider further of the subject, and communicate any suggestions which seem to me to be right and proper concerning the legislation to be asked for.

"Hon. SECRETARY OF WAR."

Your committee, after the said Senate bill had been referred to the Secretary of War for information, as before stated, and after the report and opinion of said Secretary of War had been received by your committee, thought it best to ascertain the views of the several Executive Departments named in the first section of the bill. The matter was accordingly submitted to those Departments, and, after examination by each, the general plan was adopted and approved by each of them in very strong terms. Several important amendments were by one or more of them proposed, each of which your committee have incorporated in the accompanying substitute bill, which your committee fully approve and recommend to the favorable consideration of the Senate

The accompanying substitute bill is the result of a long, patient, and careful examination and consideration of the whole subject-matter submitted to your committee by the Senate, touching the "extending of the jurisdiction of the Court of Claims of the United States, and for other purposes," so as to embrace the subject-matter of letters-patent upon inventions used by officers of the United States in the public service, and to provide suitable means for the settlement of such use of private property.

The said substitute bill is fully approved by the several Executive Departments of the Government, as containing ample provisions for the protection of the Government in all claims of the kind stated in the bill, as well as patentees or claimants claiming for the use of any patented improvement and invention.

From the foregoing communications it fully appears to your committee that, in the management of public affairs by the several Departments of the Government, there exists, in fact as well as in law, and in justice to both the Government and the citizen, a pressing necessity for the passage of a bill by which the rights of the citizen inventor as well as those of the Government of the United States, with reference to the use by that Government of that kind of property protected and secured by letters-patent, shall be fairly and properly adjudicated and determined as between them in the least expensive and most expeditious manner possible.

Such your committee believe the accompanying bill to be. We are fully persuaded that it covers the entire ground of the subject-matter contained in the several communications to which your committee have hereinbefore referred, and that it is so guarded as to protect the rights of all parties in interest fairly and equitably.

The Government of the United States has no legal or equitable right to take the property of an inventor, secured to him by the law and by the grant of letters-patent thereon, and apply the same to its own use, gain, or profit, without a just and fair compensation therefor, any more than it would have to seize the personal and real property of the citizen, and drive him and his family from their home, and, without shelter and compensation, deprive him and them of their daily earnings, or of their lands, horses, cattle, and house. Would the Government have the right to use the railroads of this country for the transportation of its mails, or for other purposes, without paying the owners for that use? Would it have the right to take the telegraph-lines of the country and convert the same to its own use without making a just compensation therefor, even in time of war? If not in war, how much less so in time of peace. As well might this Government undertake to compel persons to leave their business affairs, and to go and render service in its executive, legislative, or judicial departments without compensation therefor, as to take the patented property of the mechanic and inventor, and put the same into the public service without compensation therefor.

The Constitution of these United States stands as firmly as do stand the rock of Gibraltar between the Government and the citizen, and it there solemnly declares the fundamental law of the land to be, in these plain but positive words, to wit: "NOR SHALL PRIVATE PROPERTY BE TAKEN FOR PUBLIC USE WITHOUT JUST COMPENSATION." (See Article V of the amendments of the Constitution.)

The learned Judge Story says:

"*Private property* is the sacred right of individual dominion. It is one of the great absolute rights of every citizen of the Republic to have his property protected; and the Government has no right whatever to deprive him of it, except for the use of *the* public; and not even then without a *fair*, *just*, and *equitable* compensation. It is a well-settled principle that no man shall be disseized of his freehold or of his *private* property without full compensation therefor when taken for the use, gain, and profit of the public, by the order, or by the directions, or by a specific or implied contract on the part of the Government. This is an affirmance of a great doctrine established by the *common law* for the protection of *private* property. It is founded on natural equity, and is laid down by jurists as a principle of universal law."

The Supreme Court of the United States, in the case of Seymour *vs.* Osborne, (11 Wallace, U. S. S. C. Reports, page 533,) have solemnly decided and determined the law of this country to be that letters-patent upon mechanical invention are property, and as such may be held and owned the same as real estate or personal property, and that the inventor and his lawful representatives are justly and rightfully entitled under the law to full protection as against any one and everybody using the invention covered by such patent without license.

In that decision, among other statements, that court uses the following language, to wit:

"Inventions secured by letters patent are property in the holder of the patent, and as such are as much entitled to protection as any other property, consisting of a franchise, during the term for which the franchise or the exclusive right is granted.

"Letters-patent are not to be regarded as monopolies, created by the executive authority at the expense and to the prejudice of all the community except the persons therein named as patentees, but as public franchises granted to the inventors of new and useful improvements, for the purpose of securing to them, as such inventors, for the limited term therein mentioned, the exclusive right and liberty to make and use, and vend to others to be used, their own inventions, as tending to promote the progress of science and the useful arts, and as matter of compensation to the inventors for their labor, toil, and expense in making the inventions, and reducing the same to practice for the public benefit, as contemplated by the Constitution and sanctioned by the laws of Congress."

Upon this same subject-matter of property, and the exclusive right to make, use, and vend the same to others to be used, that learned and profound scholar and jurist, Mr. Chief-Justice Marshall, in the case of Evans *vs.* Jordan, 1 Brockenbrough's U. S. C. C. Reports, page 252, said:

"The Constitution and the law together give to the inventor, from the moment of discovery, an inchoate property therein, which is completed by suing out a patent. This inchoate right is exclusive. It can be invaded or impaired by no person, and no right can be acquired in it without the consent of the inventor."

That able and much-respected judge, Mr. Associate Justice McLean, in the case of Allen *vs.* Hunter, 6 McLean's U. S. C. C. Reports, page 306, declared and decided that—

"The law gives to the inventor the exclusive right and use of the thing invented or discovered, as a compensation for his ingenuity, labor, and expense in producing it."

Judge Nathan K. Hall, formerly Postmaster-General of the United States, in the case of Ransom *vs.* The Mayor and Commonalty of the city of New York, 1st of Fisher's Patent Cases, page 259, among other declarations and conclusions said:

"A patent when granted becomes, to a certain extent, a contract on the part of the Government with the patentee that they will protect him in the exercise of the exclusive privileges which his patent gives him."

The Supreme Court of the United States, at the December term, 1870, in the case of Burns *vs.* The United States, which, upon appeal, became The United States *vs.* Burns, 12 Wallace U. S. S. C. Reports, page 252, unanimously decided that the Government could not rightfully or lawfully use a patented invention without license of the inventor, or making compensation to him therefor. In that case that court said:

"If an officer in the military service, not specially employed to make experiments with a view to suggest improvements, devises a new and valuable improvement in arms, tents, or any other kind of war material, he is entitled to the benefit of it and to letters-patent for the improvement from the United States, equally with any other citizen not engaged in such service; and the Government cannot, after the patent is issued, make use of the improvement any more than a private individual, without license of the inventor or making compensation to him."

Such have been, upon this question of franchise, of property, and of exclusive right and title in patents, the opinions and decisions of the highest courts in this country, commencing with Mr. Chief-Justice Marshall and coming down to the present time through the circuit and Supreme Courts of the United States.

As the law now is, if the Government desires to use property covered and protected by patents, as is now very frequently the case, it must

either wrongfully and willfully violate the law by infringing the patent in the manufacture of the article desired to be used in the public service, or else contract with private individuals or companies having no license, and with whom the Government would be forced to submit to greatly advanced prices, and yet, after all that, would still be liable to the inventor or his lawful assignees for the use of the invention and letters-patent thereon, in the public service. And this the Government have no right whatever, founded in justice and a due regard for the law, to do. It cannot afford to make laws for the people to be governed by, and then violate and disregard them. The subject of the patent is regarded by the law as the *property* of the inventor alone, as "under our patent-laws it is only the *inventor*, the person in whose brain the new form or method has been conceived, who can be invested with the patent-right;" and the United States, using the same for public purposes whereby to benefit the people in their public service, ought, in equity, in common justice, and in good conscience, to pay for the same, as it would and does pay a railway company for transportation of the mails, or a telegraph company for the use of its wires in transmitting Department messages, or the farmer for his horse and wagon for the public service, or the mechanic for his day's labor, or the President of the United States, his Cabinet or other officers, for services rendered the public in *official* place.

To have a good government and full obedience to the law, the Government itself should obey the law, and in all things deal honestly and in exact justice with the humblest citizen of the republic. It cannot demand or require the service, labor, or the real or the personal property of the citizen for any purpose or use whatsoever, without a *just* and *reasonable* compensation.

Officers and other persons in the employment of this Government, who, in obedience to superior orders, make or use an invention protected by letters-patent of the United States while in that employ, not for their own use, but for the use of the Government, and that, too, in the public service, are now held liable in the circuit courts of the United States for infringement of such patent. They may be, and several have already been, enjoined and restrained by the *injunction order* of the court from either making or using the patented invention for the Government; and they may also be, and some are already, *personally held* to answer to a judgment for damages and costs and execution therefor, and their property put in jeopardy and their homes threatened and invaded by the officers of the law with the process or writ of execution for such infringement by them, in the service of the Government, through no fault of their own. Your committee are informed that there are not only several suits of this character now pending against certain officers of the Government to the great injury of the public service, but that others are contemplated, while some are actually in process of preparation. These suits are not confined to the War Department, but they extend, and are extending, to the Treasury, Interior, Navy, and Post-Office Departments, with no lawful authority on the part of the Government to stay them. They are expensive and burdensome to those officers, and they harass and embarrass the Departments in the successful management of public affairs.

It is not only apprehended, but actually suggested, by the War Department, that in all probability such officers as have been thus embarrassed and threatened with financial ruin will in due time call upon Congress to re-imburse them for such losses in damages and costs sustained by them in the public service as faithful officers obeying the

orders of their superior. The able and exhaustive report of the Chief of Ordnance, General Benét, to the Secretary of War, on the subject of the "*infringement of patents*" by the Government, and hereinbefore referred to, will give full information on this point. It is well known that such suits cannot be prevented, and that they greatly hinder and disarrange the public service in the several Departments of the Government.

There is, and there ought to be, no honorable or honest "ways and means" that this Government can devise whereby to withhold payment for the use in the public service of *property* secured for a term of years by the grant of letters-patent, and appropriated to that service by that Government. It ought to pay a *fair* and *just* compensation for that use. This would be but an act of justice and of *honest* dealing with the citizen inventor, and it would stimulate him to greater activity in the fields of invention. But for the inventive genius of the land, what would be the condition of our country to-day? What would be that of our agricultural fields? What and where would be our railroads, our steamships, our land and ocean telegraphs, our commerce, our factories, our storehouses, our shops, our mining for the deep-hidden treasures of the earth, our arts and literature, and our homes? Who, then, shall wish, for one moment even, to stay the rising tide of genius and invention, and roll back the progress of the age in which we live? Who, therefore, shall labor, or even wish, to withhold from the inventors in this country that *just* compensation which belongs to them, both by the organic and statute law, for their ingenuity, their time, their toils, and expenditure of money in creating PROPERTY in invention in the manner provided by the statute law and sanctioned by the nation's Constitution?

In conformity to the principles laid down in this report, your committee are of opinion that the Government ought to pay a *fair* and *just* compensation for the use of property vested in patents on mechanical inventions and put into the public service, and that Congress should now provide the way and manner in which and by which it can *rightfully* be done.

It is a self-evident fact that something ought to be done immediately whereby to relieve the War Department of the embarrassments and difficulties which the Chief of Ordnance sets forth so earnestly in his said annual report, and the other and several departments of the Government also have substantial relief in the same direction.

After a most careful and thorough examination of the whole case and of the official papers referred to and submitted to your committee concerning the subject-matter of the pending bill, we have come to the conclusion, and have determined, that the better way to settle and dispose of the entire subject is to recommend the passage of the accompanying bill as a substitute for Senate bill No. 571.

It will be seen by the letter of the Chief of Ordnance, General Benét, dated the 16th day of March, 1876, that Senate bill No. 571 was, by the Secretary of War, referred to the Chief of Ordnance for examination and opinion in writing thereon; and that it was examined by him, and returned with a written report indorsing the bill and recommending its passage as a sure, safe, economical, and speedy course to pursue for the settlement, award, and determination of all matters mentioned and referred to in this report as between the Government, on the one hand, and inventors on the other. Your committee are of the opinion that the accompanying bill places the Government and the inventor or his lawful representatives upon the same ground and equal footing for a proper settlement and adjudication of the rights and interests of each as to *property* in patents and the use of the same by the Government.

A general law of the kind proposed by this bill would, it is believed, protect alike all the Departments of the Government, and will relieve at once the officers thereof who have used and are now using this kind of property.

It would bring all matters relating to the use of patents before one and the same court, the Court of Claims, with the right to appeal therefrom by either party. Both courts being at the capital of the nation, the Government could the better attend the same for the purposes named in the accompanying bill.

In addition to the many reasons already given, the examination of all matters that are similar in character, embodying similar principles and facts, probably applying to one and the same mechanical construction, is placed in the hands of the same judges, who are thus better qualified to hold evenly the "scales of justice" as between nice and conflicting interests on questions of invention, of infringement, and of right, title, and ownership, as between all parties to any suit brought into court, tried and heard in the manner provided in the substitute bill.

By the passage of this bill Congress would, it is believed, be entirely relieved from the consideration of petitions or bills, or both, heretofore introduced for different persons at almost every session asking for substantially the same relief that is fully provided for in and by this bill.

The substitute bill appears to be carefully and properly guarded, so as to protect all parties in interest, no matter what those interests may be, in a fair and proper administration of justice.

Your committee, therefore, recommend the passage of the accompanying bill as a substitute for Senate bill No. 571, at an early day and during the present session of Congress.

APPENDIX R.

Water-power at Rock Island Arsenal.

WAR DEPARTMENT,
Washington, D. C., February 19, 1876.

SIR: I have the honor to transmit for the consideration of Congress, a communication from the Chief of Ordnance, inclosing a report by the commanding officer, Rock Island Arsenal, asking for an appropriation of $157,350, to complete the development of the water-power.

The agreements entered into by my predecessors under the joint resolution of Congress of March 2, 1867, makes it the duty of the United States to carry out this work to completion, and the interests of private parties require that the work should be done as speedily as possible. The whole appropriation asked for would enable this Department to complete the work and afford the relief called for in a few months, and thus fulfill the engagements entered into by the United States.

Should the full amount not be appropriated, as asked for by the Chief of Ordnance, the sum of sixty thousand dollars at least should be given, in order to enable the Department to make progress in the work.

Very respectfully, your obedient servant,

WM. W. BELKNAP,
Secretary of War.

To the SPEAKER HOUSE OF REPRESENTATIVES.

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, February 17, 1876.

SIR: I have the honor to transmit herewith a report of Maj. D. W. Flagler, commanding Rock Island Arsenal, showing the necessity for an appropriation for completing the development of the water-power.

The agreements made by the United States with the Moline Water-Power Company bind the former under the obligations hereinafter stated.

1st. Proceedings of Rock Island commission of January 24, 1867, (Executive Document 27, Senate, 2d session 39th Congress,) which requires "the Government to develop and maintain the power, so far as it can be done with the money heretofore appropriated, or that which may hereafter be appropriated by Congress for that purpose. The Moline Water-Power Company to have the use in perpetuity * * * of one-fourth of the entire water-power developed" * * *.

2d. Agreement with the Moline Water-Power Company, signed by General Grant, Secretary of War *ad interim*, and Charles Atkinson, president Water-Power Company, August 20, 1867, in which the company convey their "entire water-power," and the free use of so much of the bed of the river as may be required "for the further development of said water-power."

The Moline Company be granted the free use of "one-fourth of their entire water-power above conveyed." The United States agreeing to apply, "$40,000, or so much thereof as the War Department may consider necessary, to complete the wing-dam," &c.

3d: Agreement between the Moline Water-Power Company and Secretary Rawlins, dated April 8, 1869, which stipulates that the United States shall "resume * * * the development and prosecute to completion, &c., the upper portion of the water-power and the removal of the deposits in the pool."

Upon this subject Major Flagler, in his report of May 6, 1875, to the Chief of Ordnance, says: "I certainly believe that the obligations of the United States set forth in these papers have been thus far properly discharged, and somewhat liberally discharged, in the benefit conferred upon the Moline Water-Power Company, and that you should not feel that injustice has been done to this company by the United States. The Government has certainly bound itself to develop and maintain the water-power. What this development and maintenance shall be, is not exactly set forth, and has caused, and probably always will cause, discussion, because only one party to the benefits to be obtained has to expend the money for them." And further, it is a nice question to decide to what extent the development and maintenance shall go on, and whether the Government, which pays the expenses thereof, shall not be the judge of the manner and quantity of such development and maintenance. At any rate, the action of this Department is limited by the appropriations, and I have no doubt that full justice has been done to the interest of the Moline Water-Power Company. The necessity for further appropriations is apparent, and this Bureau has estimated for the next fiscal year, as follows:

(Book of Estimates, page 124.)

"Improvement of the water-power..... $60,000."

"NOTE.—This estimate is for opening a channel in the rock-bed of the river and improving the wing-dam, to increase the amount of water flowing into the water-power pool during low water."

This sum, however, is not sufficient to complete the work as wisdom and economy demand that it should be done, as is shown in the report transmitted herewith.

The Moline Water-Power Company feel aggrieved because the quantity of water at its disposal is not sufficient. It is admitted that the passage to the pool is obstructed, and that to give the Moline Water-Power Company, and the United States, the full benefit of the development already made, measures must be taken to cause a sufficient flow of water into the pool to supply the necessary power. The Government is bound by its agreement, (after taking possession of the water-power property,) to do this work, and in the interest of the two parties interested, for economy, and particularly for the protection of valuable interests to the United States, the work should be done now, and the entire amount, $157,350, should be appropriated.

Two methods are proposed for doing this work. Major Flagler's report, transmitted herewith, fully proves that the proper way to effect the object is by carrying out the plan proposed in that report, that it will for the least money satisfy most of the conditions and give all the water necessary for the company and the United States, and make provision for dredging out the channel, and at all times keep the work in working condition. This plan, No. 2, is therefore approved and recommended, and the money required, $157,350, should be asked from Congress at the present session.

This matter is respectfully recommended to the honorable Secretary of War for favorable action, and that it be brought to the attention of Congress.

Very respectfully, your obedient servant,

S. V. BENÉT,
Brigadier General, Chief of Ordnance.

The honorable THE SECRETARY OF WAR.

REPORT OF MAJOR D. W. FLAGLER.

ROCK ISLAND ARSENAL, ILLS., *February* 4, 1876.

SIR: Referring to my letter to you, dated May 6, 1875, respecting the deposits at the head of the water-power pool at this arsenal, the difficulty of getting a sufficient supply of water into the pool; complaints of the Moline Water-Power Company, &c.; and to the item of $60,000 in my annual estimate for the fiscal year ending June 30, 1877, for prosecuting the development of the water-power by making provision to admit the necessary amount of water into the pool, I have the honor to submit, for your information and consideration, the following calculations and remarks:

Estimate of amount of water required for the water-power, for which a water-way into the pool should be provided:

Provision should be made to furnish to the United States at least 2,000 horse-power.

The best plant of water-wheels, penstocks, and machinery cannot utilize more than 78 per cent. of the power of the water. At low water the head at the dam is 7 feet. This would require for the use of the arsenal 3,234 cubic feet of water per second,

$$\frac{2,000 \times 550}{0.78 \times 62.3 \times 7} = 3,234.$$

The contract made with the Moline Water-Power Company requires that one-third as much more be provided for the use of that company. This makes the total amount required 4,312 cubic feet per second. I think it best to put this amount at 4,400.

It is the object of this paper to determine the best method of getting this amount of water; that is, of getting it from the river into the pool. As explained in my letter of May 6, 1875, the water cannot get into the pool now, because of obstructing rocks and deposits of mud and sand. The removal of these deposits would be very expensive; is nearly impracticable, and would not be effectual in producing much lasting good.

It is, therefore, necessary to provide some other way.

Whatever plan is adopted, it should possess as many of the following requisites of a good plan as is practicable:

1st. It should be as economical as may be.

2d. It should be effectual.

3d. It should be such as will prevent future deposits of sand and mud, or such as will admit of the easiest and most economical removal of these deposits, which, unless prevented, must continue forever.

4th. The development of this part of the water-power must be such as not to prevent a future increase of the water-power, but should be such as to make such an increase as easy and economical as may be.

The future manufacturing interests of this community, and the probable future wants of this great arsenal, make attention to this last requisite important.

After discussing the only two places of development that are proposed, and making calculations and estimates for them, it will be well to see how far each fulfills the above requirements.

First plan, or that of building a long wing-dam up the river.

You are aware that the president and members of the Moline Water-Power Company have advocated the building of a long wing-dam up the river. The proposed location of this dam is shown by a red line on the accompanying map, (marked A.)

It is claimed for this plan that, by running the head of the dam into deep water, it will give so large a cross-section at the head of the pool (A B on map) that enough water will always enter the pool, and that also this dam

will raise the water in the pool nearly to the height of the river at the head of the dam. The level of the river at the proposed head of the dam (A B on the map) is 1.6 feet higher than at the present head of the pool, (C D on the map.) It is further claimed that this increased height would carry the water over the obstructions which are now at the head of the pool, thus remedying the present evil, besides giving an increased head, and a large increase of power at the water-power dams.

I have been unwilling to adopt this plan until after a thorough examination and study of this part of the river could be had.

It will be readily understood that this plan, instead of making a pool all the way to the head of the proposed wing-dam, would substantially make a canal between the wing-dam and the Illinois shore, down which all the water for the water-power would have to be brought. This canal would be more than two miles long, and generally about 900 feet wide. The water in all this part of the river is shallow. I have been afraid from the first that, to get enough water to flow down this long, shallow canal, so much fall in the surface of the water would be required that nearly all, all or more than all of the increased head, viz, 1.6 feet, would be consumed in this way, that is, that the slope of the surface of the water in the canal would be greater than outside in the river. If this were so, then, at low water, the wing-dam would dam the water out of the pool; the water in the pool would be lower than it is now, none of the benefits claimed for the plan would be gained, but great damage would be done.

During the last two years I have given much attention to this subject.

Last fall I finished complete soundings and measurements of all this part of the river. These soundings are numerous and accurate, embracing in all about 15,000 soundings. From them I have made cross-sections of the proposed canal, 200 feet apart, throughout its whole length, and from these cross-sections determined the capacity of the canal. The canal at low water would have an average depth of not much more than 1.2 feet.

Obstructions and the uneven bottom would produce eddies and *contractions*. I have, from a study of the cross-sections, determined as nearly as possible the form of bottom and sides of a canal of equal capacity for *flow*, but of a uniform cross-section at low water, and have calculated the *flow* in the latter. Of this canal the area of cross-section would be 980 square feet, the length of *wet perimeter* 830 feet, (approximately;) length of canal, 12,500 feet.

(a) To discharge 4,400 cubic feet per second through this canal, the required fall is determined by calculation to be $26\frac{5}{10}$ feet; that is, it would be impossible.

(b) If we suppose the fall in the canal to be the same that it is in the river outside, viz, 1.6, the canal would discharge $1{,}001\frac{78}{100}$ cubic feet per second, representing at the upper dam $907\frac{8}{10}$ horses' power. To get

(a) $$\text{Fall in feet} = \frac{\left(\frac{4400}{980}\right)^2 \times 880 \times .0001114}{12{,}500} + \frac{\frac{4400}{980} \times 880 \times .00002426}{980}$$

Fall in feet = 26.50.

(b) $$\text{Discharge per second} = 980 \left(\frac{\sqrt{980 \times \frac{1.6}{12{,}500} \times 8975}}{880} - .1089 \right) = 1001.78 \text{ cubic feet per second.}$$

$$\frac{1001.78 \times 62.3 \times 7 \times \frac{80}{1000}}{550} = 907\frac{8}{10} \text{ horse-power.}$$

even this we would still have to clear a channel through the rock and mud at the head of the pool.

(c) With the stage of water 1 foot above low water, to discharge 4,400 cubic feet per second, there would be required a fall of 3.598 feet, leaving the water in the pool still nearly 2 feet lower than in the river outside. With stage of water, the wing-dam would still injure the water-power, if the maximum amount of water for which the water-power is built (4,400 cubic feet per second) were required.

With the stage of water 1.45 feet above low water, to discharge 4,400 cubic feet per second, the required fall in the canal would be 1.6 feet, the same as in the river outside, and no damage would be done by the wing-dam. As the river rises above this stage, the wing-dam, if built high enough, would begin to be beneficial.

It is to be remembered, however, that the supposed improvement is only desired or needed at low water. If the determined cross-section of the canal is correct, or anywhere near correct, then the calculations prove positively that at low water the wing-dam would dam the water out of the pool and effectually destroy the water-power.

Nor is this the principal injury that the wing-dam would effect. From the instant that it is completed, the deposits in this channel must commence. It is impossible that the deposit should be less than it is now, and, even if the canal were a good one to begin with, sooner or later it must be filled up, precisely as the head of the pool is now. Then, instead of having, as we have now, the objectionable difficulty of clearing out a channel 2,400 feet long through the mud and rock, we should have the increased difficulty of clearing out and keeping clear a similar channel 12,500 feet, or nearly 2¼ miles, long. The expense of this last undertaking would make it impracticable.

Moreover, the deposit must be much *greater* than it is now. We have now the deposit only from the still water that comes into the pool. The wing-dam would give us additional deposits from the other water that does not come into the pool. It is proposed to build the wing-dam to a height of not more than 3 feet above low water. At higher stages, when the water is most charged with sediment, the river is to flow over this dam. It will then be like any other obstruction at the bottom of the Mississippi that causes a bar to form above and below it. The fillets of water below the level of the top of the dam will have from little to no current; will receive a portion of the sediment from the running water above, and, being too sluggish to carry it away, will deposit it. I believe the deposit abstracted from this water which we would not use, and from which we would get no benefit, would be more than that we now get from the water which comes into the pool and which we do use.

Some plans are proposed for washing out this deposit. They might mitigate the evil, but that they would succeed sufficiently to keep the water-power in operation at low water, is, I believe, subject to grave doubt.

COST.

To build the dam to the height of 3 feet above low water, of loose rock dumped in the river, (the cheapest construction,) would require, according to my estimate, 75,000 cubic yards, and cost $225,000.

$$\text{(c) } \frac{\text{Fall in feet}}{12{,}500} = \frac{\left(\frac{4400}{1880}\right) \times 880 \times .0001114}{1880} \times \frac{\frac{4400}{1880} \times 880 \times .00002426}{1880}$$

Fall in feet = 3.598.

It has been proposed to deepen the canal between the wing-dam and the shore, increase its cross-section, and thus avoid the evil of injuring or partially destroying the water-power at low water, as shown by the calculations herein, and to use the rock thus obtained for building the wing-dam.

This would be effectual, and is, on a larger scale, substantially the same as the other plan proposed, but to do it, it would be necessary to coffer and pump out all of this part of the river. The expense would be very great, and incompatible with the benefit obtained. The increased deposit, described on the preceding page, would still obtain. It is true that the excavation would give a smooth channel, which might be dredged, but instead of having a lesser amount to dredge from a channel 2,400 feet long, there would be a larger amount to dredge from a channel 12,500 feet long.

To make this channel at all valuable, that is, to deliver the required 4,400 cubic feet per second, and increase materially the height of water in the pool, would require at low water that the excavation clear a channel 4 feet deep and 800 feet wide. This channel would require a fall of .53 feet and save 1.07 feet of head. Its cost would probably exceed $750.

If this plan of excavating is abandoned on account of its cost, I should say then that at low water the wing-dam would injure the water-power; that if provision is to be made to bring into the pool the required 4,400 cubic feet per second, then the wing-dam would injure the water-power for any stage of water less than 2½ feet above low water; that in any case it would multiply the difficulty and cost of keeping the water-power in good condition; that it would benefit the water-power when the stage of water is 3 feet above low water, and the benefit is not needed, because then it can be obtained by other inexpensive means; that at stages of water between 0 and 3 feet above low water, if the arsenal is using little or no water and the Moline Water-Power Company is using only about 750 horse-power, then that company would get material benefit from the plan in increased head, provided that the United States keeps the water-power in order.

The other plan proposed is to excavate a channel from deep water near the head of the wing-dam now built down through the pool until deep water is reached. (See MM′ on the map.) It is proposed to make this channel 400 feet wide, 3½ feet deep, about 2,400 feet long, and to use a portion of the rock obtained in extending the wing-dam now built about 500 feet (shown on map) up-stream and out into deep water. This extension of the wing-dam would be into deep water, where the current is rapid, and should turn a part of the current into the pool, and would raise the water a few inches at this place. I estimate this raise at .32 foot, which would give a little more than 3.8 feet of water in the channel excavated.

As has been stated, there is now a deposit of mud and sand over all the head of the pool, which dams the water out of the pool. Underlying this deposit is rough, uneven rock, coming sometimes near to the surface of low water. A channel cannot be dredged through it, because the rock interferes. To dredge out the deposit over all the head of the pool would be difficult, expensive, and nearly impossible, because of the uneven rock bottom. It would not be effectual, because the deposit would soon return in the same objectionable form. The object of the proposed channel through this mud and rock is to furnish, first, a sufficient water-way into the pool, and, second, an effectual and economical method of maintaining the water-way. To determine the sufficiency of

this water-way, the calculations for flow through it give the following results:

To discharge through it the maximum amount to be provided for, viz, 4,400 cubic feet per second, would require at low water a fall of .59 foot. To discharge the same amount through it with the stage of water 1 foot above low water would require a fall of .33 foot; with the stage of water at 2 feet the fall would be .16 foot, or practically nothing. This supposes the channel to be clear of deposits.

Ordinarily the maximum amount of water would not be required. A considerable deposit in this channel might then exist and the capacity of the channel remain sufficient. In time of peace the amount of water used by the United States will be small. At such times, for many years to come, I suppose the combined consumption of both the arsenal and the Moline Company would not exceed 17.50 cubic feet per second, equivalent to 1,110 horse-power.

To discharge this amount through the channel, having in it a deposit 2 feet deep at extreme low water, would require a fall of .48 foot. With the stage of water at 1 foot, the required fall would be .12 foot. With the stage of water at 2 feet, the required fall would be .045 foot, or practically nothing.

Therefore, in time of war, or if at any time the arsenal required a large amount of power, the channel would have to be kept clear. At other times, a considerable deposit could be allowed to accumulate and the water-way still sufficient. It would be better if the depth could be increased to 4 feet; but the additional depth would cost about $40,000.

2d. The channel is also to afford an effectual and economical method of *maintaining* a water-way. If the use of the dredge cannot be avoided, then the channel would permit that the deposit be allowed to go on till it is deep, and the dredge can get a full scoop, and work economically. It would confine the dredging to a narrow channel, and give a smooth bottom to dredge over. Moreover, I hope it may prevent the necessity for dredging, or at any rate reduce very much its amount and expense.

I have provided in the lower dam four large sluice or wash gates which can be opened against any pressure of water. The other gates can be opened against the pressure of low water. By opening all the gates not in use, in both dams, a strong, rapid current would be drawn down through the proposed channel. Then, by stirring up the mud and sand in the channel by mechanical means, it is probable that the deposit might be washed out and its accumulation controlled in this way without much expense. This could be done from Saturday to Monday, when the water-power is not used.

COST.

My estimate of the cost of excavating this channel is as follows:

600 yards of coffer-dam, at $7 per yard	$4,200 00
1,100 yards of mud-coffer, at $1 per yard	1,100 00
Pumping out water	350 00
Excavating 58,000 cubic yards of mud and sand, at 30 cents per yard	17,400 00
Excavating 52,000 cubic yards of rock, at $2.50 per yard	130,000 00
Removing coffers	1,300 00
Tramways, scows, and other expenses	3,000 00
Total	$157,350 00

It is proposed to apply to this work whatever appropriation Congress

makes for this object, and to prosecute the work as indicated as fast as appropriations for it can be obtained. A less amount than that asked for could not be applied so economically as the whole amount.

I believe it would be unwise, and not economical for the Government, after having expended so much money and built so great a water-power, to leave it unfinished. It is also clear that the acts of Congress on this subject, and the contracts made with the Moline Company, require that the work shall be done.

Comparing this second plan with the first one proposed, I think it is clear—

1st. That it is more economical than the first plan; provided the first plan be made effective.

2d. That the second plan will be effective at low water, the only time when it is needed, and that at any reasonable cost the first plan cannot be made sufficiently effective to give at low water the maximum amount of water required.

3d. That the second plan admits of satisfactory and economical methods of removing the deposits that will always occur; and that the first plan would increase these deposits, and would furnish no satisfactory or economical method of getting rid of them.

4th. If the first plan were carried out, it seems to admit of no future increase of the water-power, except by digging out, through rock, the channel 2¼ miles long, between the proposed wing-dam and the Illinois shore; a work so expensive that I doubt if it would ever be undertaken.

If the second plan is carried out, and at any future time (50 years hence) the wants of the arsenal and manufacturers in this region demand it, certainly the water-power can be increased, at a reasonable cost, by deepening the channel.

In the calculations for *flow* in the channel between the proposed wing-dam and the Illinois shore, (first plan,) the cross-section of available channel was taken, for low water, at 980 square feet. If this cross-section is correct, then the results obtained in the calculations for flow are very nearly correct. It may be claimed that this cross-section is too small. Certainly if a larger cross-section is the true one, it would give better results. But, discarding all calculations, this much is true: The discharge of the Mississippi at this point at low water has been carefully measured and calculated, and is not more than 17,000 cubic feet per second. Not more than one-tenth of this flow is in the part of the river under consideration, at extreme low water. To partition off this part of the river from the rest could not in any way increase its flow. Leave the slope of the surface the same that it is now, and the discharge is 1,700 cubic feet per second, equivalent to about 1,100 horse-power.

The water in the pool cannot be raised without diminishing the slope or fall of the channel above. To diminish this, means diminish the flow and diminish the horse-power. Building the wing-dam would then confine us to 1,100 horse-power as a maximum. It would dam us off from getting any more, and to get this an opening would have to be cut down through the rock and deposits now at the head of the pool.

If, however, the water-power is to be reduced to, say, 1,000 horse-power, and be constructed for the present needs of the Moline Company only, then the slope in the channel above can be diminished; the surface of water in the pool will be raised, and the small increase of head at the water-power dam, so much desired, will be gained. But the deposit will at once commence, and, unless cleaned out, will sooner or later reduce the power at low water to 0.

I regret the length of this paper, but the subject could not be very well explained in less space. As it is, much has been left out that is pertinent to the subject. The matter could be explained verbally much better while using the maps and drawings.

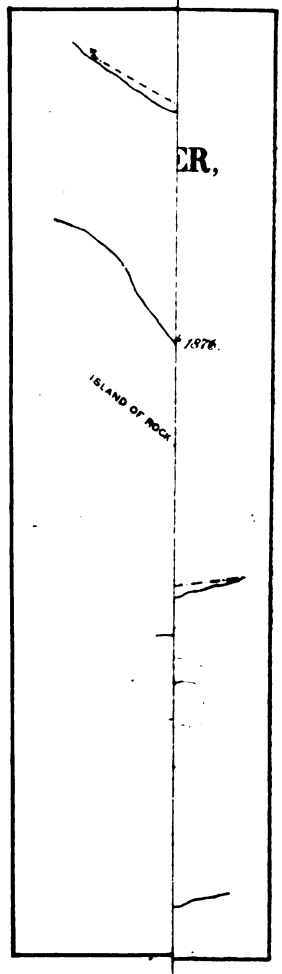
Very respectfully, your obedient servant,

D. W. FLAGLER,

Major of Ordnance, Bvt. Lieut. Col., U. S. A., Commanding.

To the CHIEF OF ORDNANCE,

United States Army, Washington.



of a war to promptly supply all our forts with their complements of sound and suitable powders.

I regret the length of this paper, but the subject could not be very [illegible] that is

APPENDIX S.

Deterioration of powder caused by storage in sea-coast forts.

UNITED STATES ORDNANCE AGENCY,
New York City, February 2, 1876.

SIR: Referring to your communication of the 7th ultimo, requesting information regarding the loss in value in powders resulting from the deterioration caused by storage in our sea-coast forts, I have now to submit the following report, accompanied by the inclosed statements and estimates bearing on the question.

This office can only judge of the extent of the deterioration by its experience derived from examinations made from time to time, and from the conditions of powders which have been sold through its agency since the war.

Statement No. 1 (covering a period of five years) exhibits that of 7,106 barrels stored in our sea-coast forts, 4,505 barrels were found to have become unserviceable, or say 63 per centum.

It is a fair conclusion to draw that the entire quantity, other than that reported on statement No. 1, stored on the sea-coast, subject to the same deteriorating influences of the damp sea-air, has deteriorated in the same ratio as has been found by our experience at this point.

At present 30,000 barrels of powder (see statement No. 2) are stored, from sheer necessity, in the forts of our different harbors; and judging from the results of our discoveries here it is thought that the equivalent of, say, 19,000 barrels has probably fallen below the standard of serviceability for the want of a suitable powder-depot for storage and proper care and preservation.

As a supply of 60,000 barrels of powder is a moderate one to be kept on hand to meet the sudden emergencies always incident to the opening of a war, the special and peculiar powders necessary for sea-coast armaments especially requiring time to manufacture, an estimate of the extent of the damage which would result from the common use of our sea-coast magazines should be considered on the basis of the above-mentioned amount.

This amount would cost the United States at present prices (averaged) say $1,500,000.

After five years' subjection to the deteriorationg influences of sea-coast storage, it is fair to estimate (from our experience quoted above) that say 50 per centum would fall below the required standard of serviceability and would probably be eventually disposed of either as unserviceable or damaged powder; besides, the powders classified as serviceable would be probably impaired to a serious extent.

The loss on this basis it is therefore estimated would be, say, $540,000, allowing a price of seven cents per pound as the market-value of unserviceable and damaged powders.

The inclosed estimate (marked No. 3) based upon the results of the inquiries of the Board on Arsenals, reference to which in this connection is respectfully invited, and the cost of suitable magazines as erected at Saint Louis arsenal, gives an aggregate of $600,000 as the cost of a suitable reservation for a powder-depot and all the necessary appointments for an establishment commensurate with our present and prospective wants, and is so located (see report) as to enable us in the event of a war to promptly supply all our forts with their complements of sound and suitable powders.

I may mention in this connection that powders kept in our arsenal magazines do not, from our experience, suffer any deterioration, as a rule, other than that incident to years of storage.

In conclusion, I would respectfully invite attention to the following extract from the report of the Board on Arsenals of 1874:

"In concluding this part of the report, it is deemed well to allude to the immediate necessities of a suitable powder-depot for the Atlantic coast.

"In the establishment of our present arsenals, as their locations at the time of their construction were but sparsely settled, the erection of powder-magazines on these Government reservations provided for our wants in this respect.

"The rapid increase of population in the adjacent towns and cities has, however, in the majority of cases, rendered these magazines dangerous to the communities in which they are located, and hence the Government either has abandoned, or eventually will have to abandon, the storage of powder at all of our arsenals.

"The damp sea-air renders our fortifications unfitted for this purpose, and the Government has now large quantities of powder rapidly deteriorating at these places for want of proper storage facilities. About 2,500 tons of powder and 3,000 tons of niter are now on hand.

"The necessity of immediate action is hence deemed, it is believed, apparent, and it is earnestly recommended that Congress be asked at its next session to appropriate a sum adequate to purchase a site and commence the provision of buildings suitable not only for the storage of powder, but also for our niter supplies, and the accommodation of suitable machinery and appliances for the manufacture of experimental powders."

Very respectfully, your obedient servant,

S. CRISPIN,

Brevet Colonel U. S. A., Lieutenant-Colonel of Ordnance, Commanding.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

STATEMENT No. 1.

Memorandum showing the condition of powders stored in under-mentioned sea-coast forts, overhauled, and condition ascertained, covering a period of five years, from 1871 *to* 1875, *to wit:*

Year.	Posts.	Cannon.		Mortar.		Musket.		Total.
		Sound.	Damaged.	Sound.	Damaged.	Sound.	Damaged.	
		Barrels.	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*
1871..	Fort Pickering, Mass.	200	600	.....	.....	.....	.....	800
1872..	Fort Columbus, N. Y..	53	104	129	378	.....	.....	664
1873..	Fort Warren, Mass ...	1,000	334	900	311	.....	.....	2,545
1875..	Fort Adams, R. I.....	.....	828	.....	795	.....	.....	1,623
1875..	Fort Schuyler, N. Y...	307	861	12	221	.....	73	1,474
	Total	1,560	2,727	1,041	1,705	.....	73	7,106

RECAPITULATION.

Total number of barrels overhauled, 7,106; of which 2,601 barrels were serviceable and 4,505 barrels damaged, or 63 per cent.

STATEMENT No. 2.

Statement of the quantities of powder on hand, stored at the arsenals and at the sea-coast forts, during the years 1871 *and* 1875.

	Barrels.
Arsenals, 1871	40,560
Forts, 1871	31,000
Total	71,560
Arsenal, 1875	*17,585
Forts, 1875	30,000
Total	47,585

STATEMENT No. 3.

Estimated cost for the purchase of a site for a powder-depot, the erection of magazines and other buildings, improvement of grounds, and the construction of rail-communications between the depot and the Erie Railroad.

Five magazines to be constructed of brick, each 200 feet by 50 feet, and 12 feet clear between floors and ceilings, to accommodate 60,000 barrels of powder	$400,000 00
Quarters, stables, and other necessary buildings	75,000 00
For purchase of site of, say, 1,000 acres, at $40 per acre	40,000 00
Constructing wagon-roads, bridges, drains, inclosing-fences, and other improvements to grounds	60,000 00
Constructing railroad to establish connection between Erie Railroad and the depot a distance of 2½ miles, at $10,000 per mile	25,000 00
Total	$600,000 00

* 14,480 barrels are at Saint Louis, Mo., arsenal.

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